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THE AËRONAUTICAL SOCIETY AND THE WAR.

In the midst of appeals for many Funds, when international finance is so shaken that many dependent on investments are uncertain of their solvency, when common prudence counsels economy, who cares to go round with the hat for his own benefit? Yet this is an unblushing appeal by the Aëronautical Society for the subscriptions of its members. Not a new appeal, nor to a new audience. Only the times are new and, some would say, most unfavourable. Why not wait awhile till things have settled down a little? For this reason. **The Society depends for its existence upon the subscriptions of its Members.** Good wishes, good intentions, are pleasant accompaniments of more material help; they are merely paving for the broad and easy way unless reinforced by the sinews of war.

After many years of struggle and anxiety, this last year or two has seen the Society established on a sound basis; a growing membership, increasing prestige, and a small balance to the good each year. Increasingly did it seem that ere long a little more of the great work before the Society might be within the compass of its finances. It was realised that the reserves were slight, almost non-existent. No prosperous aeronautical engineers had yet donated grateful posthumous gifts to their Scientific Society, for the reason that the position of prosperity when it has come into contact with Aeronautical Engineering has been akin to the position of Algy soon after he met the Bear. The urgent work that lay before the Society could not, however, be neglected until large invested funds were at its back, it must be done at once. As to how well that work has been done let others speak.

The Right Hon. Lord Sydenham, F.R.S., than whom no one is more qualified to speak on Imperial Defence, said when presiding on the occasion of Colonel Sykes' lecture on 4th February last:—

"**In conclusion, I wish to express my conviction of the national importance of the work which the Aëronautical Society is carrying on. It is necessary in this country, especially at the present time, to keep naval and military needs constantly before the not too enlightened mind of the man in the street. By explaining what is being done, by discussing the conditions and possibilities of**

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aeronautics, by securing co-operation between civil scientists and the Services, and by reminding Governments of their responsibilities, I believe this Society is doing very valuable and patriotic work."

At the Wilbur Wright Memorial Banquet, on the 19th May, 1914, the following tributes were paid to the Society:—

"It falls to be said by anyone who has had to play a part in the development of flying in this country that the Aëronautical Society, by its quiet and persistent scientific work and also by the brilliant achievements of some of its Members, . . . has rendered a service to flying which we ought to acknowledge, and which I believe will put this country before long in the front rank of the nations in the conquest of the air. . . . That this has been achieved in so short a time must be a cause of gratification to all those who, . . . when they said that one day there would be an Air Service of almost more importance than any other, were regarded as dreamers and fools. That to-night we should see gathered together here Members of our Society and distinguished guests, three Members of the Army Council, a prominent Member of the Naval Forces, brilliant flyers, . . . that we should have done that must be a source of gratification to us. But we do not mean to let it rest here, and if I may express the views of the Aëronautical Society, of which I am proud to be a Member, I believe I may say this, that we will not rest until we can say that, in this matter of conquering the air, if conquered it ever shall be, Great Britain and Ireland shall be the first." (Col. the Right Hon. J. E. B. Seely, D.S.O., M.P.)

"With regard to your Society I beg on behalf of the Army Council to thank you for the great assistance which it has rendered the Army. Your most interesting lectures and their discussions form a valuable mine of information for us. And it is, I am sure, in the nature of comrades and colleagues that your Members are looked upon by our officers." (Major-General S. B. von Donop, K.C.B., Master-General of the Ordnance.)

"The Aëronautical Society confers great benefit upon other branches of Science, . . . upon engineering for instance. There is not the slightest doubt that aeronautical study is helping engineering materially. . . . I am sure that we (the Institution of Electrical Engineers) as an Institution will be very pleased to do everything in our power to help the Aëronautical Society." (William Duddell, Esq., President of the Institution of Electrical Engineers.)

It was with this appreciation to hearten it that the Society ended last Session's meetings.

And then, when all preparations were being made for a new Session's lectures, when long overdue expenditure was being devoted to re-organising the Library, when schemes were being considered for widening the scope of the Society's appeal, came the war. It was clear that much of the Society's activities would be immediately curtailed—papers which in any way gave away information of value to the enemy could not be read, discussed, or published, while those which did not would be of so little vital interest as not to earn an audience in the time of crisis before us.

A proportion of Members had omitted to pay their subscriptions before the crisis, and it is to them that an appeal is now addressed particularly. Unless those Members liquidate their debt the great proportion of the comfortable balance which the Society would have had to start the new year will not materialise. This fact makes keen economy in the running of the Society essential. For the future financial commitments must be the least that are compatible with usefulness. The Journal will appear, but will return to more modest proportions than of late.

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The date on which the Society can resume its full functions depends on the course of the war. It must not be thought, however, that the Society is now quiescent. Meetings will not be held this side of Christmas, but as soon as it is felt that a meeting can be held with profit it will be called, and meantime the Council have decided that the staff and rooms of the Society should be placed at the disposal of the Government. The offer is being taken advantage of, and the Army Council are most kindly making some pecuniary acknowledgment to the Society of services now being rendered by the staff.

The Society therefore confidently appeals to all its Members to support it on National grounds through the present and coming crises, with the determination that the end of the war will see it emerge stronger and more ready to undertake the great work that lies before it of fostering the science of aeronautics in Great Britain, the science which has enabled Great Britain to equip a Flying Corps that has already been (in Sir John French's words) "of incalculable value" in the present crisis, the science which is perhaps the most pregnant of all for Great Britain's future.

This appeal cannot be better concluded than by quoting the following words from a letter written on 2nd October from the front by General Sir David Henderson, D.S.O., in response to the Society's congratulations when the first despatches showed how brilliantly the Royal Flying Corps had won its spurs:— "Undoubtedly we owe much to the Society, and we shall endeavour to repay our debt by giving to the Society all the information of scientific interest which may be gathered in this novel experience."

Notices of the Aëronautical Society of Great Britain.

Members on Active Service.

It is desired to keep a complete record at the Society's Offices of Members serving in His Majesty's Forces during the war, and the Secretary would be glad to receive names of those who have joined from civilian life since the commencement of the war or who have rejoined after retirement.

The Most Hon. the Marquess of Tullibardine, M.V.O., D.S.O., a Vice-President of the Society, who was appointed Lieutenant-Colonel (temporary Brigadier-General), August 15th, has been appointed a Brigade-Commander, and the Chairman of Council, Major-General R. M. Ruck, C.B., R.E., has been gazetted for Active Service as a Chief Engineer, October 22nd.

Associate Fellows' Election.

As a result of the ballot for Associate Fellowship, the following have been elected:—Major B. F. S. Baden-Powell, Leonard Bairstow, Harold Bolas, F. E. Cowlin, A. Fage, C. R. Fairey, Lieut. J. N. Fletcher, R.F.C., Major H. Musgrave, R.F.C., J. L. Nayler, S. J. Norton, M. A. S. Riach, G. T. Richards, J. Schiere, F. J. Selby, N. A. V. Tonnstein.

Technical Terms Committee.

The Technical Terms Committee have completed their first list of terms, which has been issued to the Press, and is printed in the present issue.

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Library.

The Council desire to thank Professor M. F. FitzGerald for copies of "Flapping Flight of Aeroplanes" and "On Flapping Flight"; Mr. Harold Sadler for a copy of "Aerostation: A narrative of the Aerial Voyage of Mr. Wyndham Sadler across the Irish Channel, July 22, 1817," and "An Authentic Narrative of the Aerial Voyage across the Irish Channel by Mr. Sadler, October 1, 1812," together with a coloured engraving of Mr. Sadler and part of the balloon with which he ascended from Dublin, October 1, 1812.

OBITUARY.

LIEUTENANT RICHARD T. GATES.

We deeply regret to record the death of Lieutenant Richard T. Gates, which occurred on the 14th September, from injuries received while descending from a patrol flight on the night of Thursday, September 10th.

As everyone knows, the late Member was the maker of the London Aerodrome, and on the outbreak of war, when the Aerodrome was taken over by the Royal Naval Air Service, he was commissioned as Flight Lieutenant for special service. It was while returning from a night reconnaissance above London that Lieutenant Gates apparently misjudged his distance above the ground, was hurled from his machine when it struck the ground, and sustained amongst other injuries a dislocated neck. The extent of the loss that aviation has sustained will only be fully realised when, after the war, the London Aerodrome is faced with the difficulty of finding his successor.

The funeral took place, with full naval honours, on Thursday, September 17th, at Hendon Church. The Society sent a wreath, and was represented by Mr. J. H. Ledeboer, B.A.

LIEUTENANT-COMMANDER THOMAS FLEMING BESANT, R.N.

We very much regret to have to record the death of Lieutenant-Commander Thomas Fleming Besant, R.N., a member of the Society since 1909. He was in command of the Australian submarine A.E.1 when she disappeared recently with all hands.

The dead officer, who was 30 years of age, was a nephew of the late Sir Walter Besant, the famous novelist, and lived at Chatham. His skill as a seaman may be judged from the fact that under his command the A.E.1, with her sister ship A.E.2, travelled the 12,500 miles from Portsmouth to Sydney under her own power early this year, escorted by only a small cruiser.

TECHNICAL TERMS COMMITTEE.

Members of the Committee.

L. Bairstow, A. Graham Clark, Captain T. O'B. Hubbard, Archibald R. Low, Mervyn O'Gorman, C.B., Dr. T. E. Stanton, Lieutenant-Colonel F. H. Sykes (representing the War Office), Lieutenant E. D. M. Robertson, R.N. (representing the Admiralty).

In view of the urgent necessity for settling as soon as possible certain terms, it has been decided to publish as an instalment the list of terms annexed hereto. The absence of terms dealing with Stability in the present list is due to the fact that a comprehensive set of such terms, together with others, is under consideration and will be published in due course.

WORD.	DEFINITION.

A

AEROFOIL—A structure, analogous to the wing or tail of a bird, designed to obtain a reaction from the air approximately at right angles to the direction of its motion.

AIRSCREW—Used as a generic term to include both a propeller and a tractor screw. See "Screw."

AILERON—See "Balancing Flap."

ALIGHTING CARRIAGE—See "Carriage."

ANGLE, DIHEDRAL—In geometry the angle between two planes. The wings of an aeroplane are said to be at a dihedral angle when both right and left wings are upwardly or downwardly inclined to a horizontal transverse line. The angle is measured by the inclination of each wing to the horizontal. If the inclination is upward the angle is said to be positive, if downward, negative.

ANGLE, GLIDING—The angle between the horizontal and the path along which an aeroplane, in ordinary flying attitude, but not under engine power, descends in still air.

ANGLE OF INCIDENCE OR ANGLE OF ATTACK—The angle a wing makes with the direction of its motion relative to the air. The angle is usually measured between the chord of the wing and the direction of motion.

ATTITUDE—An aeroplane's or wing's position relative to the direction of motion through the air.

B

BACK, TO—Of the wind, to change direction counter-sunwise (counter-clockwise).

BALANCING FLAPS—Aerofoils used for causing an aeroplane to roll about its longitudinal axis for the purpose of balancing.

BALLONET—A word taken from the French meaning "a little balloon" and exclusively limited to an interior bag containing air, within the envelope of an airship.

BANK, TO—To heel for the purpose of turning.

BODY—Of an aeroplane—that part which usually contains the engine, crew, tanks, etc., and to which the wings, carriage, and other organs are attached.

BRACING—A system of struts and ties to transfer a force from one point to another.

C

CABANE—A French word to denote the mast structure projecting above the body to which the top load wires of a monoplane are attached.

CABRÉ—Tail-down.

CAMBER (of a wing section)—The convexity of a wing section. The camber is usually measured (as a fraction of the chord) by the maximum height above the chord.

CANT, TO—To tilt; to take any inclined position.

CARRIAGE—That part of the aircraft beneath the body intended for its support on land or water and to absorb the shock of alighting.

CHASSIS—See "Carriage."

CHORD—The straight line (taken conventionally fore and aft unless otherwise specified) touching the under surface of an aerofoil at or near the leading and trailing edges. The length of the chord is the projected length of the section on the chord.

CLINOMETER—See "Inclinometer."

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WORD. DEFINITION.

CONTROL LEVER—On an aeroplane, a lever by means of which the principal controls are worked. It usually controls pitching and rolling.

CROSS SECTION (of an Aerofoil)—The section cut by a fore and aft plane normal to the surface (commonly the under surface).

D

DIHEDRAL ANGLE—See under "Angle."

DIVE—To descend steeply with the nose of the aircraft down.

DOPE, TO—Of fabrics—to paint a fabric with a fluid substance for the purpose of tightening and protecting it.

DRAG—The resistance along the line of flight; the head resistance. Compare "Drift."

DRIFT, TO—To be carried by a current of air or water; to make leeway.

DRIFT—The distance drifted. The speed of drifting. The word "drift" having a well accepted nautical significance should be avoided as far as possible in the sense of "head resistance" or "drag."

E

ELEVATOR—An aerofoil set in a more or less horizontal plane and hinged on an athwartships or transverse line. It is used for controlling the angle of incidence of the aeroplane.

ENTERING EDGE—See "Leading Edge."

F

FAIRING—A piece added to any structure to reduce its head resistance or drag.

FINS—Subsidiary aerofoils set parallel to the normal direction of motion of an aircraft.

FLAPS, BALANCING—See under "Balancing."

FLAPS, WING—See under "Balancing."

FUSELAGE—See under "Body."

G

GAP—The distance between the upper and lower wings of a biplane. For specific purposes the points between which it is measured should be indicated.

GLIDE, TO—To fly, usually on a descending path, when the aircraft is not under engine power.

GLIDING ANGLE—See under "Angle."

I

INCIDENCE, ANGLE OF—See under "Angle."

INCLINOMETER—An instrument for measuring the angle of slope of an aircraft, referred to the horizontal.

L

LEADING EDGE—Of a wing—the forward edge.

LEEWARD—Away from the wind.

LEEWAY—Lateral drift to leeward.

LIFT—The force exerted by the air on an aerofoil in a direction perpendicularly or nearly so to the motion. Usually upwards in ordinary flight.

LONGITUDINALS—Of an aeroplane, the long fore and aft spars connecting the main with the subsidiary supporting or controlling surfaces.

LONGERON—See "Longitudinal."

P

PANCAKE, TO—To descend steeply, with the wings at a very large angle of incidence, like a parachute. Contrast "Dive."

PITCH, TO—To plunge in the fore and aft direction (nose up or nose down). Contrast this with "Roll."

PITOT TUBE—A tube with open end facing the wind, which, combined with a static pressure or suction tube, is used in conjunction with a gauge to measure fluid pressure or velocities.

PRESSURE HEAD—A combination of pitot tube and static pressure or suction tube, which, in conjunction with a gauge, is used to measure fluid pressures or velocities.

PRESSURE TUBE, STATIC—A tube (usually with holes in its side past which the fluid flows) so designed that the pressure inside it equals the pressure exerted by the fluid on any body at rest in the fluid. Used as part of a pressure head.

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WORD. DEFINITION.

PROPELLER—An air-screw behind the main supporting surfaces. Compare "Tractor."

PYLON—A mast or post.

R

RIB—Of a wing, a light fore and aft member which carries the fabric for the purpose of giving the desired cross section to the wing.

RIB, COMPRESSION—A rib designed to act as a strut between front and rear spars of a wing.

ROLL, TO—To turn about the fore and aft axis.

RUDDER POST—The main post of a rudder.

RUDDER—A subsidiary aerofoil (in an aeroplane more or less perpendicular to the main supporting surfaces) by means of which an aircraft is turned to right or left.

RUDDER BAR—The foot-bar, by means of which the rudder of an aeroplane is worked.

S

SCREW, AIR—An aerofoil so shaped that its rotation about an axis produces a force along that axis for driving an aircraft.

SIDE DRIFT—See "Drift."

SIDE SLIP, TO—In an aircraft, to move more or less broadside on relatively to the air.

SKID—A part of the alighting gear of an aircraft arranged to slide along the ground.

SPAN, OF WINGS—The distance from wing tip to wing tip.

SPAN, OF AEROPLANES—The maximum transverse dimension.

SPAR—A long piece of timber or other material. In a wing, either of the beams which run transversely to the aircraft, and transfer the lift from the ribs to the frame and bracing.

STAGGER—Of wings. When the wings of a biplane are set with the upper one slightly ahead of, or abaft of the other, they are said to be staggered. The stagger is measured by the angle made by the line joining the leading edges with the normal to the fore and aft axis of the aeroplane. It is convenient to call the stagger positive if the upper wing is ahead of the lower.

STATIC PRESSURE TUBE—See under "Pressure."

STATOSCOPE—An instrument to detect the existence of a small rate of ascent or descent.

STRAINER—An appliance bearing a suitable mesh for straining impurities from petrol and other fluids. Also compare "turnbuckle."

STREAM-LINE—The path of a small portion of a fluid, supposed continuous, moving relatively to a solid body. The term is commonly used only of such paths as are not eddying, but the distinction should be made clear by the context.

STRUT—A structural member intended to resist compression in the direction of its length.

T

TAIL—The after part of an aircraft, usually carrying certain controlling organs.

TIE—A structural member intended to resist tension.

TOP SURFACE CAMBER—See under "Camber."

TOP LOAD WIRES—See under "Wires."

TOP WARP WIRES—See under "Wires."

TRACTOR—An air-screw mounted in front of the main supporting surfaces.

TRACTOR MACHINE—An aeroplane with air-screw mounted in front of the main supporting surfaces.

TRAILING EDGE, OF A WING—The after edge.

TURNBUCKLE—A form of wire tightener.

U

UNDER-CARRIAGE—See "Carriage."

UNDER-SURFACE-CAMBER—See "Camber."

V

VEER, OF THE WIND—To change direction sunwise (clockwise).

VELOCITY OF SIDESLIP—The speed with which the craft moves broadside on with respect to the air. Distinguish from "drift," q.v.

WORD.	DEFINITION.
W	
WARP, TO	Of a wing, to bend so that the outer end of the back spar moves up or down. It is convenient to call the warp positive when the movement is downwards.
WING FLAPS	See "Balancing Flaps."
WINGS	The main supporting organs of an aeroplane. A monoplane has two wings, a biplane four.
WIRES, LIFT	Wires, the principal function of which is to transfer the lift of the wings to the body or other part of the aeroplane structure.
WIRES, WARP	Lift wires connected to the back spar and controlled so as to move its outer end down for the purpose of warping the wing.
WIRES, TOP LOAD	Wires intended mainly to resist forces in the opposite direction to the lift.
WIRES, TOP WARP	Top load wires connected to the back spar and passing from wing to wing to allow the wings to warp.
WIRES, DRAG	Wires, the principal function of which is to transfer the drag of the wings to the body or other part of the aeroplane structure. Wires intended mainly to resist forces in the opposite direction to the drag are sometimes called "anti-drag wires."
WIRES, DRIFT	See "Wires, Drag."
WIRE-STRAINER	See "Turnbuckle."
Y	
YAW, TO	An aircraft is said to yaw when its fore and aft axis turns to right or left out of the line of flight. The angle of yaw is the angle between the fore and aft axis of the aircraft and the instantaneous line of flight.

THE PRESSURE DISTRIBUTION ON AN AEROPLANE WING IN FLIGHT.

BY W. ELLIS WILLIAMS, B.SC., ASSOCIATE FELLOW.

A very large amount of valuable work has been done in measuring the forces on models of aeroplane surfaces placed in a wind channel, and the results obtained are of the greatest value to the designer. Doubt has however been thrown on the applicability of the results obtained to calculations referring to the full-size aeroplane in flight,* and it is of great importance to obtain definite information regarding the corrections, if any, which should be applied to the wind channel results. The experiments described below were made with the object of comparing the pressure-distribution on an aeroplane wing in flight with the distribution measured on a model of the same wing in a wind channel. The measurements were carried out on an aeroplane constructed by the writer, which for the purpose of the experiments was flown over the sands at Llanddona, on the east coast of Anglesey. The beach at this place is an ideal one for experiments of this nature, there being a stretch of hard level sand obtainable fully three miles long and over a mile broad. The machine was a single-seater monoplane with a large triangular tail. Its plan form is shown in Fig. 1.

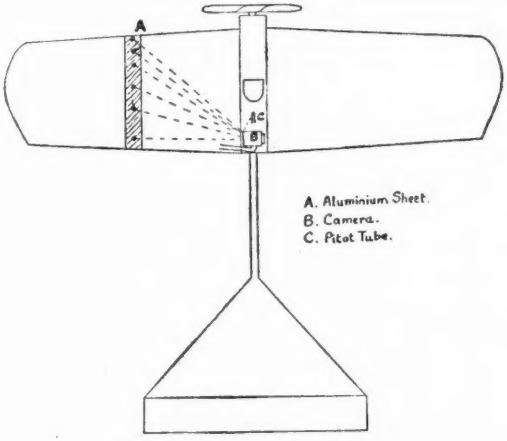

FIG. 1.—PLAN OF AEROPLANE.

The Pressure Measuring Apparatus.

In order to measure the pressure-distribution on the wing a band was cut from sheet aluminium, long enough to reach round the middle of the wing, and just broad enough to cover the space between two ribs. In this sheet twelve holes were drilled along a central line, and in each hole a brass tube about 3/16" diameter was fixed by means of a flange and nut, the flange being afterwards filed down so as to be practically flush with the surface of the sheet. The aluminium sheet was now fitted over the wing in the position shown and nailed down to the ribs, the brass tubes projecting inwards through holes in the fabric. Each tube

* Vide "Essais d'Aerodynamique," Duc de Guiche, 1912.

was connected to the measuring instrument by a narrow rubber tube which passed through the interior of the wing to the body of the machine.

The instrument used for measuring the pressure was a kind of box camera, shown in sectional plan and elevation in Fig. 2. In the front of the box instead

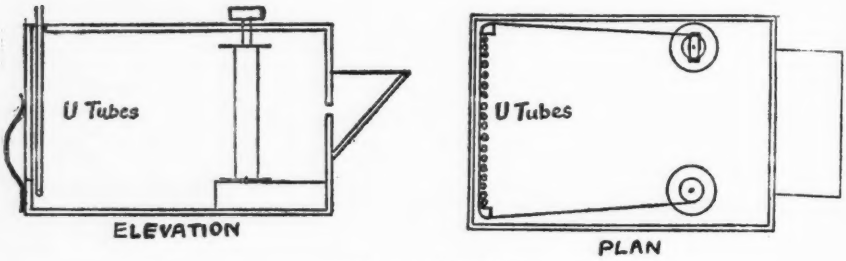

FIG. 2.—CAMERA.

of the lens a slit $\frac{1}{2}''$ wide was cut, extending about half the width of the box, and in front of it was placed a plate glass mirror inclined at an angle of 45° to the side of the box, so that it reflected light through the slit into the interior of the box. At the other end of the box were placed twelve glass gauge tubes of the usual type for measuring air pressure and a couple of **U** tubes for measuring the angle of inclination of the machine. These were arranged as shown in Fig. 3 and nearly filled the end of the box. The bend of each gauge was filled

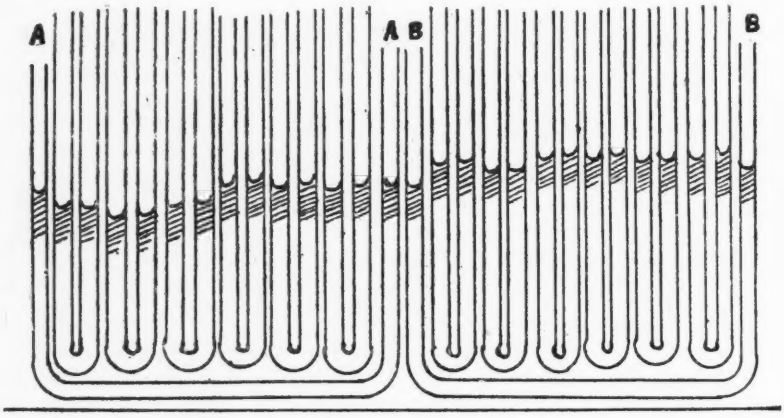

FIG. 3.—GAUGE TUBES.

with a plug of cotton wool to damp out the oscillations of the liquid. In the interior of the box two film spools were mounted so that a strip of bromide paper could be wound from one on to the other in the way that the film is wound in a Kodak camera. The bromide paper passed behind the gauge tubes and was pressed against them by a spring acting on the back cover of the box. The gauge tubes were filled with petrol, and the light from the slit cast a sharp shadow of the surface of the liquid on the bromide paper, so that after exposure

and development the difference of level of the petrol in the two limbs of the gauge could be measured to a quarter of a millimetre. One end of each gauge tube was open to the box and the other connected by rubber tubing to the holes in the wing. The inside of the box communicated by means of a wide tube with the interior of the wing and thus the gauges measured directly the difference of pressure on the two sides of the wing fabric. A gauge similar to the others connected to a Pitot tube served to measure the velocity of the machine. The Pitot tube was fixed on an upright screwed to the *cabane* of the aeroplane and was about 6′ higher than the body, being thus placed well out of the propeller slip stream. A flap shutter was placed in front of the slit, and could be opened from the pilot's seat by pulling a string, an exposure of half a second being sufficient to give an image on the paper.

The Inclinometer Device.

The angle of inclination of the wing to the horizontal was obtained from the readings of the two **U** tubes, A B, Fig. 3. After filling the gauges with petrol the machine was held with the chord of the wing horizontal and the difference of level of the petrol in the two middle limbs measured. The change in this difference divided by the distance between the two limbs gives the angle of inclination of the wing to the horizontal in radians. In order that this may also be the angle of incidence of the air on the wing it is necessary that the flight path of the machine should be horizontal, and that there should also be a complete absence of vertical air currents. The first condition is also necessary for correct reading of the gauges as a vertical acceleration of the machine alters the effective value of gravity. The determination of the true angle of incidence is indeed the most difficult part of the experiment, as the pressure-distribution is exceedingly sensitive to small changes in the angle of incidence. Measurements in the wind channel have shown that the pressure on point (1) on the top of the wing changes from .79 to .27 as the angle varies from 10° to 8°. In order to obtain the best results the experiments were made at sunset, in the nearest approach to a perfect calm which was observed over a month's time, and the machine during flight was kept on a level course about seven feet above the ground. By thus keeping close to the ground one was certain that the results would not be affected by vertical currents and it was also much easier to make certain that the machine kept a horizontal course. It is possible, of course, that the proximity of the ground may affect the flow of air about the wing and thus alter the pressures, but as the actual height of the wing above the ground is much greater than the span the effect cannot be very great. It was hoped that this point could be examined by making an experiment in the wind channel, placing the wing near the floor, but unfortunately the direct effect of the floor on the velocity of the current masks the effect of the wing and makes the results inapplicable to the aeroplane. The two cases would only be similar if the sides of the channel moved with the wind.

The Actual Open-air Experiments.

The actual experiment with the machine was carried out as follows:—The engine having been started the spool in the camera was turned so as to bring a fresh piece of paper behind the tubes; the aeroplane was then released, and having lifted a few feet above the ground was kept on as level a course as possible. After going a few hundred yards the shutter was opened and an exposure taken. The paper was then developed and fixed and the heights of the columns measured with a sliding vernier calliper.

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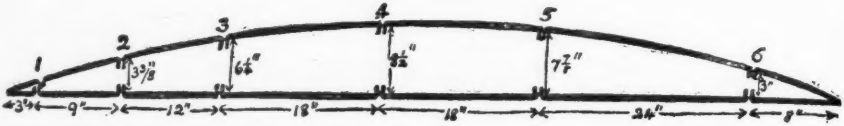

FIG. 4.—SECTION OF WING AT AA SHOWING POSITION OF HOLES.

The following are the readings obtained, the numbering of the holes being the same as in Fig. 4:—

September 3rd, 1913. Barometer 29.95″.
Speed of machine 2.8 cms. = 55 feet per sec.
Angle of incidence as measured 9° 45′.
Height above ground estimated at 7′.

Number of Hole.	Top Surface Suction.	Bottom Surface Pressure.
1 ...	2.40 cms. ...	1.42 cms.
2 ...	1.20 ,, ...	1.05 ,,
3 ...	1.50 ,, ...	.90 ,,
4 ...	1.60 ,, ...	.42 ,,
5 ...	.88 ,, ...	—
6 ...	.17 ,, ...	.10 ,,

The curve is plotted in Fig. 5.

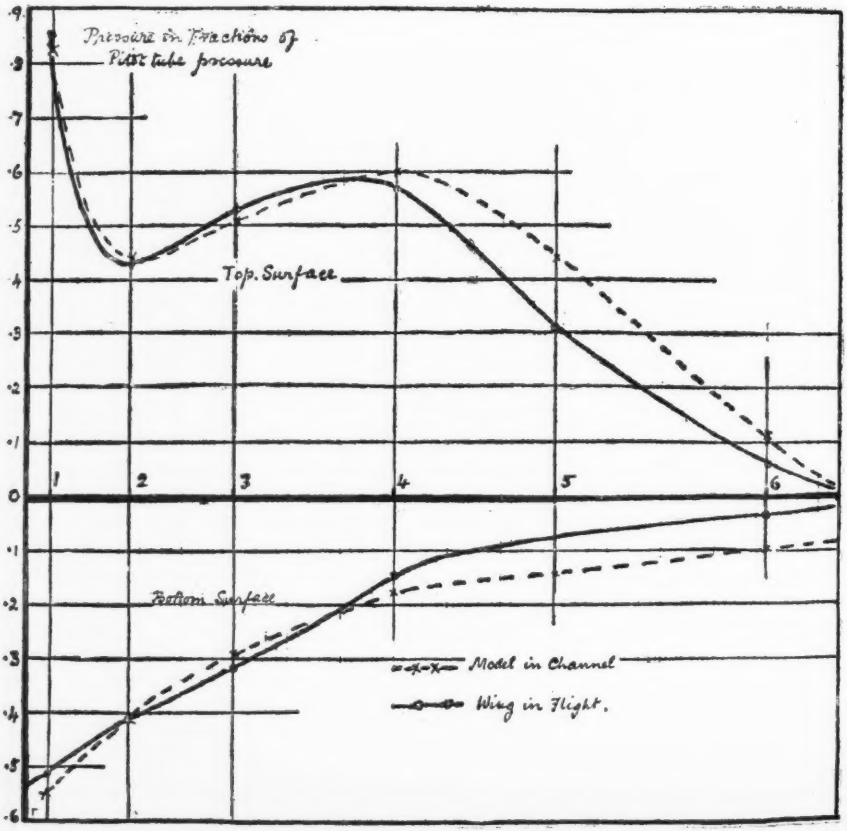

FIG. 5.—PRESSURE DISTRIBUTION ON WING AND MODEL.

The section of wing is similar to Eiffel No. 7 and the pressure curve is of the same general form as the one given by him. The suction on the upper part is greatest at the forward edge, it diminishes rapidly to a minimum at the second hole, then increases to a maximum near the middle of the wing, and finally diminishes nearly to zero at the back edge. The pressure on the lower surface is greatest at the forward edge and diminishes continuously across the wing.

Wind Channel Tests for Comparison.

In order to get wind channel results for comparison with the above an exact model of the wing was made of wood, one-tenth full size. This was tested in a channel of four feet diameter, the air being drawn through by a screw propeller type fan attached to the axis of a 7 h.p. induction motor. Six holes were drilled in the model in corresponding positions to those in the aeroplane wing. These holes were connected, one at a time, to a pressure gauge of the same type as those previously employed, the other side of the gauge being connected to the static pressure tube of the Pitot gauge, and thus a pressure distribution curve was obtained.

The following table gives the results:—

Speed of air current 31′ per sec.
Angle of incidence 9° 45′.

Number of Hole.	Top Surface.	Bottom Surface.
1	.38	.34
2	.18	.26
3	.22	.218
4	.252	.140
5	.20	.128
6	.00	.10

The results are also plotted in Fig. 5. In this figure the pressure readings for the wing and the model are divided by the corresponding speed reading so as to make them directly comparable, and the zero of the model readings is also shifted so as to get the best coincidence between the curves. This is necessary because the pressure in the inside of the wing from which the pressures at the different points were measured, depends on the position of the openings in the wing and is not necessarily the same as the pressure in the static tube.

Conclusions to be Drawn.

On comparing the two curves it will be seen that the values for model and for wing are in very good agreement for all holes except Nos. 5 and 6, for which the pressures on the model are considerably greater than those on the wing. This is almost certainly due to the wing being slightly warped at the moment of exposure, although an effort was made to have the warp exactly neutral at the moment of exposure. Apart from these two holes the values agree with one another within the limit of experimental error and show that wind channel experiments may be relied on to give accurate results when applied to actual full scale machines.

ON THE FLIGHT OF PTERODACTYLS.

BY

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It is perhaps unfortunate, from the point of view of aviators, that the extinct flying reptiles known as "pterodactyls" or "pterosauria" no longer exist. There can be no doubt that in the case of the more highly evolved members of the group the organisation was more specialised for flight than that of any other animal of which we have knowledge. Other flying animals can walk, run, or swim, besides fly. But in the case of the higher pterodactyls their structure is such that it is difficult to understand how they can have had any other means of progression than flying. With a body little larger than that of a cat they had a span of wing asserted in some cases to have reached 21 feet or more.[1] These huge wings were so constructed that it was impossible for them to be furled against the body as happens with the wings of birds and bats. Only the outer half of each wing could be bent backwards in the direction of the body (Fig. 1). With such partially furled wings it may be asked how they could possibly swim if they ever alighted on the water over which they flew.

That pterodactyls were incapable of progressing as quadrupeds is proved by the fact that, as will be further explained below, the fore limb was incapable of movement in a fore and aft direction at either the shoulder or elbow joints.[2]

If they ever walked on their hind legs they could only have done so with the wings extended, as otherwise the wing-tips would have trailed along the ground.

Perhaps the most feasible method of progression for them when on land is that, having alighted on their feet, they fell over on their stomachs and pushed themselves along, after the manner of penguins, by means of the hind legs, perhaps with an occasional slight lift from the wings for surmounting an obstacle.

That they could hang by their hind legs from the boughs of trees, as is the custom with bats, is improbable for various reasons. It is not every bough that

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[1] A statement has recently appeared in a semi-popular scientific magazine to the effect that the air of the present day could not support animals of such large span as the larger pterodactyls, and that consequently the barometric pressure in Cretaceous times must have been about twice as great as it is now. But it may be doubted whether there is so great a difference between birds of the present day and pterodactyls in respect of span as the author of this theory believes. Pelicans reach a span of fifteen feet. Latham ("General History of Birds," Vol. X., p. 48, 1824) gives records of the span of albatrosses of 10, 11, 12, and 13 feet. He mentions the "Voyage from England to India in the year 1754," by Ives (Edward), formerly Surgeon of Admiral Watson's ship and of His Majesty's Hospital in the East Indies, on p. 5 of which appears :—"An albatrose (*sic*), a sea fowl, was shot off the Cape of Good Hope, which measured 17½ feet from wing to wing. A shark was also caught, and brought on board the *Cumberland*, with 72 young ones in her belly, each from 6 to 14 inches long." A gentleman in India gave to one of us a detailed account of his shooting and measuring a bird, stated to be an adjutant, with a span of 18 feet. No reason can be given for believing that the largest existing birds would become incapable of flight were the earth to undergo a great reduction of atmospheric pressure. Large birds of heavy loading, such as the black vulture, can soar as well at a height of two miles above the earth's surface as at lower levels. At such a height the barometric pressure normally stands at about 20 inches. There is reason for believing that pterodactyls were of much lighter loading than the black vulture.

[2] A restricted range of fore and aft movement could occur at the wrist joint, but, as will be shown later, this was so connected with movements of rotation as to be singularly ill adapted for purposes of progression.

could support their weight, which in the larger specimens is supposed to have reached 20lbs. A bat flies with head first and hind legs stretched out behind. In order to grasp the bough with its feet it has to check speed ahead, which it does by " poise-flapping " at the same time rotating round the transverse axis. As soon as its feet are thus brought forward they grasp the bough and the bat rapidly furling its wings falls over in one direction or another to reach the head downwards position. But in view of the large span of its wings the pterodactyl could only attempt " poise-flapping " above the topmost twigs of the tree, which

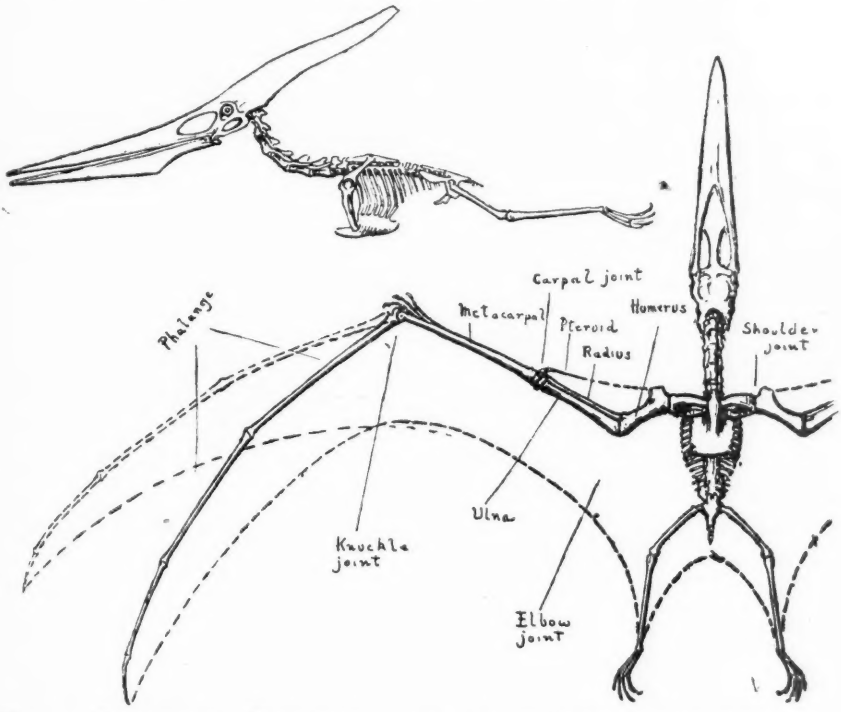

FIG. 1. PTERANODON. VIEW FROM BELOW, AND SIDE VIEW OF BODY WITH WING REMOVED.

twigs would be quite incapable of supporting its weight. If it chose a bough of sufficient size and therefore nearer the trunk it is quite certain it could only have attempted poise-flapping with imminent risk of tearing or breaking its wings.

On the other hand, there can be no doubt that they were fully adapted for life in the air. Throughout their organisation weight-saving has been carried to an extreme. The hollow air-filled wing bones of vultures were heavy columns compared with the delicate empty tubes that supported the wings of pterodactyls. These tubes were made of hard bone material scarcely thicker than a visiting card. At the two extremities the bones were strengthened internally by delicate struts and bands of bone of paper-like thinness. The bones of the hind limb, the vertebræ, and even the phalanges of the wing-finger were hollow and filled with air. Striking illustrations of these facts may be seen in the specimens exhibited in the British Museum (Natural History), South Kensington.

Remains of the larger pterodactyls are found in some cases in strata of marine origin under circumstances that make it probable that they habitually flew at some such distance as a hundred miles from the nearest land.[3] They seem to have been mainly fish-eating in habit.

In view of the extreme specialisation of the pterodactyls for flight the construction of their wings is a matter of great interest. Owing to the above-described delicacy of the bones the remains met with as fossils are usually so crushed that it is impossible to discover the mode of action of the different joints. Some exceptionally perfect examples of the bones of the pterodactyl Ornithodesmus have recently come into the possession of the British Museum (Natural History). From a study of these and other specimens we are now in a position to describe the movements of which the different joints of the wing were capable. Our account is founded entirely on the Cretaceous forms. The articular surfaces are described from uncrushed specimens in perfect preservation from the English Wealden and Cambridge Greensand. The different specimens agree in the shape, number and arrangement of their articular facets, and further agree exactly with those of similar bones of Pteranodon in the British Museum (Natural History). Ornithodesmus is stated by R. W. Hooley[4] to have had a span of five metres "allowing for the natural curve." If the wing bones were placed in contact, end to end, in a straight line, a span of more than five metres would be obtained. But as the bones of the wing were habitually held in a slightly flexed position at the different joints Hooley reduces his estimate of the span to five metres.

As indicated by the name "pterodactyl," the wing is formed by the bones of the arm together with the phalanges of one enormously elongated finger. The structure of the wing was such as to permit movement at the shoulder, elbow, wrist, and knuckle joints (Fig. 1). The wing-finger is formed by four phalanges, but these bones were fixed together by bony union in some cases and there is no reason for thinking that movements could occur in any case at the different joints of the finger.

In the case of birds and bats the shoulder joint is a ball and socket joint. Thus the wing can not only be flapped up and down, but it can also be advanced and retired. As has been shown by one of us such advancing and retiring is used by the bird or bat for the purpose of changing the position of the "lift" in relation to the centre of gravity and for thus causing movements round the transverse axis.[5]

But in the case of the later pterodactyls the shoulder joint was a hinge joint that only permitted motion vertically up and down. A wide range of such movement could occur as in the shoulder joint of birds. In that there is absolutely no sign of curvature of the facet of the joint in the anterior posterior direction, we regard it as certain that no advancing or retiring of the wing could occur at the shoulder joint of the later pterodactyls. The flapping up and down at the shoulder joint was in a perfectly vertical direction. Thus, movement at this joint was suitable for high speed flapping flight. Flapping downwards and forwards, which is necessary for slow speed flight of birds, could not be accomplished by movements of the shoulder joint of pterodactyls without further adjustments. It may be noted that there was no possibility of any movement of flexing backwards of the wing against the body as occurs at this joint in birds. That

[3] G. F. Eaton, "Osteology of Pteranodon." (Memoirs of the Connecticut Academy of Arts and Sciences, New Haven, Vol. II., July, 1910.)

[4] "On the Skeleton of Ornithodesmus latidens, an Ornithosaur from the Wealden Shales of Atherfield (Isle of Wight)." (*Quarterly Journal of the Geological Society*, Vol. LXIX., June, 1913, No. 274, p. 372.)

[5] E. H. Hankin, "Animal Flight," p. 156. (London: Iliffe & Sons, 1914.)

is to say, pterodactyls could not furl their wings against the body by movements at the shoulder joint.

We will now consider the elbow. In the case of birds the elbow is a hinge joint that permits of extending and flexing movements in the horizontal plane. Flexing at this joint is used in furling the wing. In the case of pterodactyls the elbow joint was also a hinge joint. The direction of permissible movement was not horizontal as in birds. It was not vertically up and down as at the shoulder joint of pterodactyls. It was between these two directions. Whereas flapping downwards at the shoulder was vertically downwards, flapping downwards at the elbow was not vertically downwards but in a direction that made an angle, so far as we can judge, of nearly twenty degrees with the vertical.[6] Thus, movement at the elbow joint would give flaps in a downwards and forward direction. If there was nothing more to be said we might conclude that such flapping downward and forward occurred and was required for slow speed flight, as in the case with birds and bats. But before drawing this conclusion the matter requires discussion.

In the first place birds advance their wings for slow speed flapping flight both to compensate for the travelling backwards of the lift as speed decreases and also in order that the flapping should produce more lift qua flapping proportionate to the decrease of " pull " with its consequent decrease of life due to gliding. That a gliding action and consequent lift occurs during flapping flight is shown in " Animal Flight," p. 222. Now the above suggestion as to the method of slow speed flapping in pterodactyls is not excluded on the ground that the suggested method would produce no " rotation up " round the transverse axis. It would be an advantage to the pterodactyl if it could increase lift qua flapping while keeping the long axis of its body horizontal and therefore in the most suitable position possible for speed ahead. But the above suggestion is excluded on the ground that it takes no account of the backward travel of the lift. This would require to be compensated by an advance of the wings or of part of the wings. No advancement is possible at either the shoulder or elbow joints. Neither, as will be shown below, could there be advancement at the wrist joint lasting through both the up and down strokes. But advancement could be produced, as will be explained in a later paragraph, by increase of extension of the outer part of the wing by movement at the knuckle joint. But if this occurred there would be rotation upwards round the transverse axis and flapping from the shoulder joint would then be downwards and forwards. Hence, the suggested movement at the elbow joint would be superfluous.

In the second place the range of movement at the elbow joint is only about 30 degrees. This is quite insufficient for ordinary flapping flight, whether slow or fast. It would only be sufficient for " half flaps," which in the case of birds only occur in flight under certain infrequent atmospheric conditions.

Thus the first suggested explanation of the movement at the elbow joint having failed we must look for another. Let us first examine more minutely the structure of the joint.

The bones that enter into this joint are the arm bone or humerus, and the bones of the forearm, namely, the radius and ulna. In the human arm the outer end of the radius is not fixed firmly to the outer end of the ulna. The attachment permits of a certain amount of sliding so that the end of the radius can slide round the end of the ulna. This movement is connected with rotation of the hand by movement at the wrist joint. In pterodactyls the radius had no power

[6] Imagine lines drawn along the greatest diameters of the facets at the two ends of the humerus. When seen in an end-on view of the humerus these two imaginary lines make an angle with each other, which we measured in two cases, and found to be 18° and 19° respectively.

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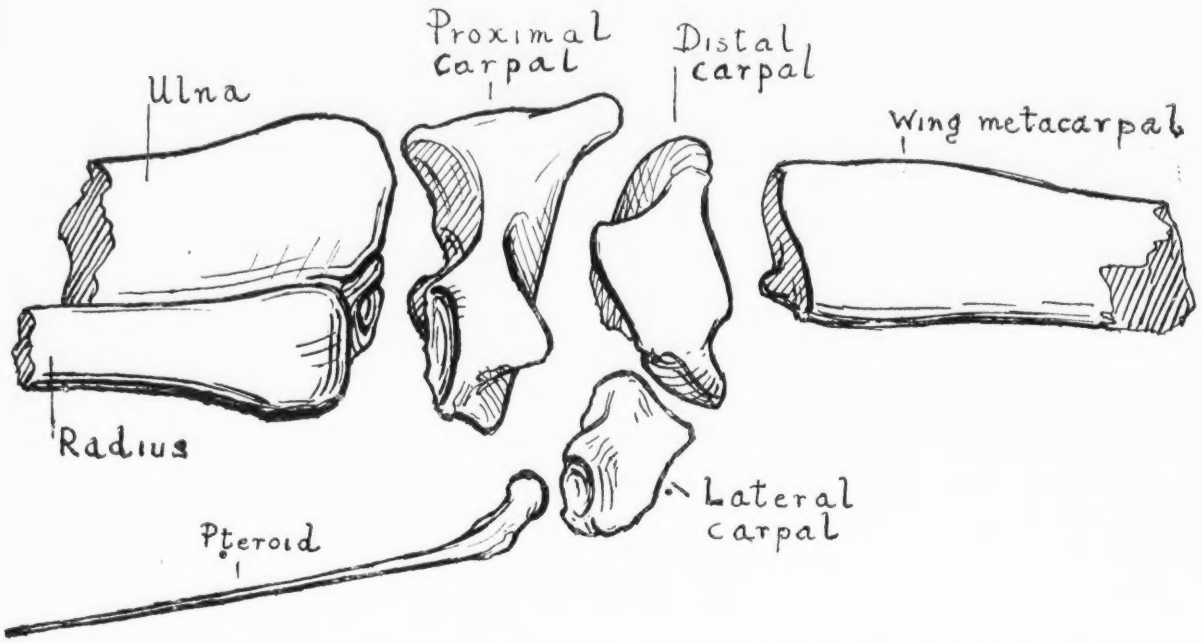

FIG. 2. ORNITHODESMUS. VIEW FROM IN FRONT OF LEFT WRIST JOINT WITH BONES DISARTICULATED.

of movement of this nature. But the radius could slide in the direction of its long axis through a distance of nearly a quarter of an inch (in Ornithodesmus). The long axes of the two bones the radius and ulna are parallel to each other and remain parallel during this movement. In other words the radius could take up two extreme positions which we may describe as the "inward position" and the "outward position." The elbow, as stated above, is a hinge joint. The surface with which the radius articulated is not of quite regular curvature. The irregularity is such that the radius assumes the "inward position" when the forearm is raised up as far as possible. It assumes the "outward position" when the forearm is directed downwards as far as possible.

That this in-and-out displacement of the radius actually occurred is proved by the fact that there are two articular surfaces on the radius and ulna where they come into contact with each other near each extremity, which surfaces must obviously have facilitated the movement.

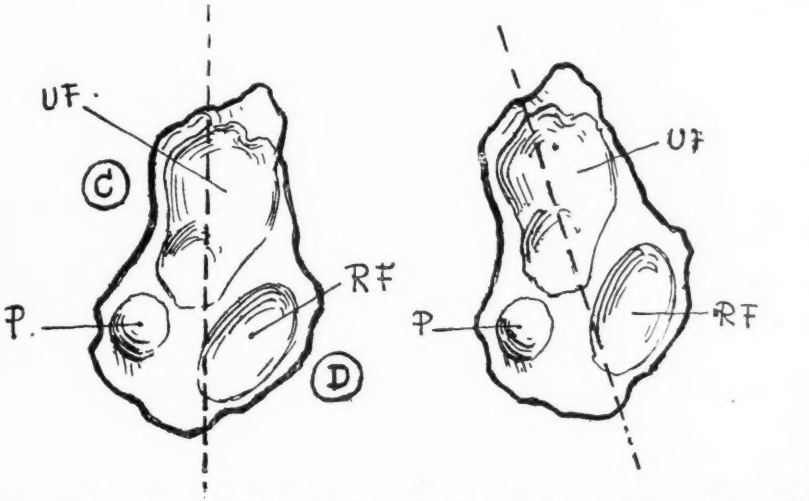

FIG. 3. VIEW FROM BODY SIDE OF LEFT PROXIMAL CARPAL BONE. A BEFORE AND B AFTER RECEIVING PUSH FROM RADIUS.

The fact that the radius had this singular power of movement obviously throws no light on the function of the elbow joint. To discover the meaning of the movement it is necessary to consider the effect of the movement of the radius on the bones of the wrist joint.

A front view of the wrist joint with the bones disarticulated for the sake of clearness is shown in Fig. 2. The distal[7] end of the radius is seen lying in front of the distal end of the ulna. On the outer or wing-tip side of the joint is shown the proximal end of the metacarpal of the wing finger. Between these bones are shown the two chief bones of the wrist which are known as the "proximal carpal" and the "distal carpal."

We must first consider the movement that occurs on the proximal side that is on the body side of the proximal carpal.

Fig. 3 shows the inner surface of the proximal carpal as seen in end on view

[7] The two terms, "distal," meaning the side furthest from the body or from the centre of the object described, and "proximal," meaning nearest the body, are in common use in anatomy, and might be found useful in other sciences.

from the direction of the body of the animal. At the lower and posterior part of this surface is seen a projection P. This fits into a corresponding depression on the end of the ulna. Thus, the lower side of the end of the ulna was pivoted at this spot. The upper part of the outer end of the ulna rested against the curved surface UF. The outer end of the radius rested against the facet RF.

As stated in previous paragraphs the radius can slide for a short distance in the direction of its own length. When it does this it pushes RF. This push from the radius has the following consequences.

Firstly, there is a slight rotation of the wrist (relatively to the ulna) round the pivot P. The direction of the rotation is indicated by the two diagrams in Fig. 3. It results in a rotation upwards of the metacarpal bone round its long axis.

Secondly, there is rolling in the direction DC. Before the movement the letter C and the letter D in the diagram may be regarded as having been equidistant from a pair of points placed one on each side of the end of the ulna. After the rolling one point on the ulna is further from D while the other point is nearer to C. This movement is equivalent to a retirement combined with slight depression of the outer part of the wing. In the more perfect specimens of the smaller pterodactyls in the South Kensington Museum the wing bones are

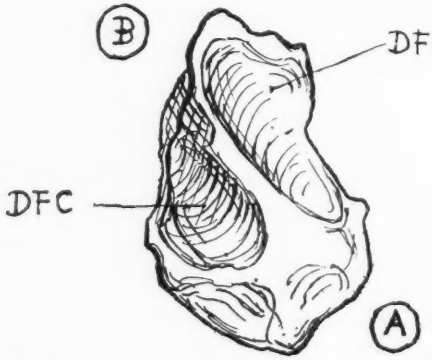

FIG. 4. VIEW FROM WING-TIP SIDE OF LEFT PROXIMAL CARPAL BONE. DFC, DFC, FACETS FOR ARTICULATION OF DISTAL CARPAL BONE.

seen to be retired at the carpal joint through an angle of between 30° and 40° in the absence of any sign of displacement of the bones. It is probable that in life the bones could only be retired through a slightly smaller angle.

In order to avoid confusion it is advisable to refer to the part of the wing supported by the metacarpal (Fig. 1) as the "wing-front." The term may also be applied to the part of the wing near the carpal joint in gulls. In each of these cases the wing-front probably played a part in wing adjustments similar to that of the wing-tip of vultures.

Now let us consider the movement at the outer surface of the bone we have just been discussing. A view of this surface of the proximal carpal bone is shown in Fig. 4. There are two articular surfaces DFC separated by a ridge. Movement of the outer wing bones at this joint took the form of a rolling movement

in the direction BA. The base of these wing bones may be regarded as equidistant from the letters A and B before the movement. After the movement part of the base had approached A and part had receded from B. This rolling movement was of very slight extent. One of the articular surfaces was larger than the other. It is probable that slight sliding occurred on this larger surface. The first of these movements must have slightly retired and markedly depressed the wing-front. The second must have rotated it upwards.

The movements just described were those between the proximal carpal and the distal carpal bones (Fig. 2), the so-called " intracarpal joint."

The movement between the distal carpal and the base of the wing metacarpal was a simple rotation. As indicated in Fig. 5, on the outer surface of the distal

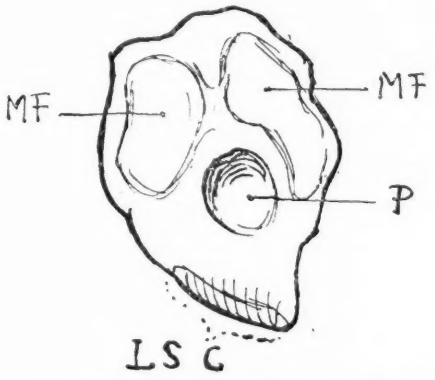

FIG. 5. END-ON VIEW FROM WING-TIP SIDE OF LEFT DISTAL CARPAL BONE. P DEPRESSION FITTING PEG ON BASE OF WING METACARPAL (SHOWN IN FIG. 2). MF, MF, ARTICULAR FACETS FOR ARTICULATION WITH BASE OF WING METACARPAL. LSC ARTICULAR SURFACE OF LATERAL CARPAL.

carpal there is a depression P which fits a projecting peg on the inner end of the metacarpal. The articular surface of the metacarpal sliding over the facets MF caused a rotation of the wing metacarpal round the point P as a pivot. Thus, the wing metacarpal could rotate round its long axis. The permissible movement must have been of very small extent.

One more movement remains to be noticed, namely, that at the knuckle joint K, Fig. 1. This was a hinge joint permitting extension and flexion in the horizontal plane. This was equivalent to advancing and retiring not of the wing-front but of the wing-tip. There is a projection at the base of the wing phalanx which must have served for the attachment of an " extensor " tendon and which may have limited the forward movement of the wing-tip. The fully advanced position of the wing-tip is indicated by the dotted outline P′ in Fig. 1. This full advancement must have been used for producing " rotation up " round the transverse axis, since at no other part of the wing could movement occur suitable for producing this effect. The probable position assumed in ordinary slow speed gliding flight is indicated by the continuous line P. The wing-tip could be retired till it pointed completely backwards or even could be turned in towards the body of the animal.

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The movements of which the different parts of the wing are capable are summarised in the following table:—

JOINT.		MOVEMENT.	REMARKS.
SHOULDER		(1) Downwards	Of wide range
ELBOW ...		(2) Downwards and slightly forwards, possibly with slight rotation downwards of wing-front	Inseparably connected
WRIST ...	Fore-arm and proximal carpal	(3) Rotation up of wing-front (4) Large retirement (about 30°) of wing-front with slight depression	Inseparably connected
	Proximal carpal and distal carpal	(5) Slight retirement with large depression of wing-front (6) Rotation up of wing-front	Inseparably connected
	Distal carpal and wing metacarpal	(7) Rotation up of wing-front	Slight
KNUCKLE		(8) Advancing and retiring of wing-tip	Of wide range

Of these different movements, that at the shoulder joint needs but little discussion. In view of what is now known about the mechanics of flight, it is permissible to suppose that movement at this joint was used principally for flapping, that high-speed flapping occurred with wing-tips retired, and that the wing-tips were advanced when flapping at slow speed and when starting or ending a flight.

Movement of the elbow joint need not be separately discussed, as it could only occur in unison with certain movements of the wrist.

As may be seen from the table, the different parts of the wrist joint were capable of no less than five different movements, some of which were inseparably connected. We have to consider whether these movements occurred together or in groups and what was their function.

It is a rule that if the same movement can occur at two positions in a joint

it will usually occur at these two positions at the same time and in the same direction. The movements occur in such a way that one reinforces the other. The reason for this fact is that " flexor " and " extensor " tendons are usually inserted not on the bones of a wrist, for example, but pass over it and are inserted on the bones of the hand beyond the wrist. But in the present case movements (3) and (4) are inseparably connected with movement of the elbow (2). Hence if the elbow is kept fixed, movements (5), (6), and (7) might occur independently of (3) and (4).

Movements (3) and (4) occurred with, and no doubt were at least to some extent caused by, movement of the elbow. To understand the probable causation of movements (5) and (6) it is necessary to refer to *Fig. 2*. On the underside of the joint is seen a bone Pt, known as the " pteroid bone." In the later pterodactyls this is a small tapering splint of a bone that has the appearance of having represented the insertion of a tendon.[8] As is indicated in *Fig. 2*, it was attached to the lateral carpal bone (by a movable joint), and this again was attached to the distal carpal. The position of these bones was such that a pull on this supposed tendon would have caused movements (5) and (6). Of these (6) was a rotation up of the wing-front. It is not necessary to assume that there was a separate tendon with similar function attached to the base of the wing metacarpal to produce movement (7), for as soon as movement (6) had progressed far enough to allow air pressure on the under side of the wing-front, this pressure would of itself cause movement (7).

If we admit that the pteroid bone represents a pteroid tendon, we are obliged to assume that there was another tendon whose pull would reverse the movement caused by the pteroid. We may provisionally refer to this supposed tendon as the " antipteroid." We have no means of deciding whether this tendon was inserted on to the distal carpal or whether running in a curved course over that bone, it was inserted into the base of the wing metacarpal. In the latter case its pull would reverse movement (7) besides (5) and (6). In either case, we are probably safe in regarding movement (7) as merely a continuation of (6), and not requiring separate consideration.

The different movements could have been combined in the following ways :—

A. If the elbow is depressed, then (apart from any effect from the pteroid) there is—

(3) Rotation up of wing-front.
(4) Slight depression of wing-front (besides the depression due to fore-arm movement).
(4) Large retirement of wing-front.

B. If elbow remains fixed (and also if it is depressed), the pull from the pteroid causes—

(6) Rotation up of wing-front.
(5) Large depression of wing-front.
(5) Small retirement of wing-front.

[8] The small size of this bone—9.6 centimetres in a pterodactyl of 15 metres span—renders it unlikely that it supported a propatagium in the manner suggested by one of us. (" The Development of Animal Flight," *Aeronautical Journal*, Vol. XVI., p. 28, January, 1912.) In the paper here quoted reasons are given (on aeronautical grounds) for believing that the earlier pterodactyls had four wings, of which the hinder pair were supported by the hind legs. Stromer has recently stated that one of his museum assistants recollects seeing a beautifully preserved specimen of the pterodactyl Rhamphorhyncus in the shop of a dealer some ten years ago, and that this specimen showed a wing membrane supported by the hind leg and passing from the fifth toe of the hind foot to about half way along the tail. This statement appears to deserve further investigation, and if the specimen is still in existence, it would be of great interest for it to be examined and described. Stromer states that the tail fin of Rhamphorhyncus was horizontal, and not vertical, as has hitherto been supposed to be the case. Thus the only instance that has been adduced of the use of a vertical fin by a flying animal turns out to be a myth. (Ernst Stromer, " Bemerkungen zur Rekonstruktion eines Flugsaurier-Skelettes," Zeitschrift der Deutschen Geologischen Gesellschaft, Vol. 62, 1910, Berlin, footnote on p. 88.)

C. If elbow remains fixed, then the pull from the antipteroid tendon causes :—

(—6), (—7) Rotation down of wing-front.
(—5) Large elevation of wing-front.
(—5) Small advancement of wing-front.

Of these combinations, it may be noted that C could only occur in the absence of A and B. On the other hand, A and B could occur either together or separately.

We appear to be on fairly safe ground in concluding that the above is a substantially accurate statement of the facts of the case as to the extraordinary mechanism of the wrist joint of the pterodactyl. In the case of the human wrist the " flexor " and " extensor " tendons work independently of rotation and in whatever position of rotation assumed by the joint. The human wrist is a joint adapted for many purposes. In the case of the pterodactyl the " flexor " and " extensor " tendons could only work in connection with and in proportion to rotation of the wrist. It is a joint adapted to one purpose. In view of the high degree to which the movements are inter-related, it is impossible to imagine that any of them are accidental. The movements have been adapted and specialised for one purpose, and we are obliged to conclude that this purpose was flight.

Besides the wrist joint, the whole organisation of the pterodactyl shows that it was fully adapted and specialised for life in the air. But the most extraordinary inference that we are obliged to draw from the structure of the pterodactyl is that the muscles for flapping the wings were extremely weak in comparison with those of birds. The evidence for this fact is the small size of the ridge on the sternum to which these muscles are attached. If the small size of this ridge was the only fact we knew about pterodactyls, we might well conclude that they were land or sea animals that only occasionally rose into the air. But there is no doubt, from other facts, that they were pre-eminently air-frequenting in their habits. Thus the small size of the flapping muscles leads us to suspect, not that they flew worse than birds, but that they flew more scientifically.

The weakness of the flapping muscles makes it highly probable that their habitual mode of flight was by soaring, rather than by flapping. The absence of a wing-tip capable of lifting the wing-front to a large degree, as occurs in the case of vultures and adjutants, indicates that their soaring could not have resembled the slow speed circling of these birds of heavy loading. The retirement of the wing-tip caused the wing of the pterodactyl to have an outline somewhat like that of gulls and albatrosses. The implied suggestion that their flight was like that of an albatross agrees well with the little we are able to infer about their habits.[9]

The weakness of the muscles for flapping the wings renders it highly improbable that they could indulge in " poise-flapping," a form of flight that requires rapid beats of large amplitude. Thus it is improbable that they poised in the air and plunged down suddenly on their prey, as does the pied kingfisher.

The light construction of the wing bones and the weakness of the pectoral muscles renders it improbable that they could indulge in any kind of flight that

[9] The albatross and certain other of the larger soaring birds resemble pterodactyls more than do other birds in the lightness of the structure of their wing bones. It is probable that the wing membrane of the larger pterodactyls was attached to the hind legs. Hence the pull from this membrane must have tended to draw the legs apart. The muscles that could have opposed this tendency must have been weak, judging from the curiously small size of the pelvis. This weakness of the muscles suggests that the wing membrane was extended across from one hind leg to the other, an arrangement that would diminish the work required from the leg muscles. An analogy for such an arrangement for the hinder part of the volant membrane is given by the vampire bats where there is an interfemoral membrane in the absence of a tail capable of aiding in its support.

requires a sudden change of speed. It is not likely that they could dive through the air by "shoulder descent," and check speed suddenly in the air in the manner employed by vultures. Neither is it likely that they could plunge into the water as do gulls, in view of the fact that they were unable to furl the wings against the body, and in view of the possible difficulty of rising again from the water in any but the calmest weather.

If their flight was habitually like that of the albatross, and therefore at high speed under certain atmospheric conditions, and if the frailness of their build renders it improbable that they could check speed suddenly, it is probable that they could check speed gradually while in the air and while gliding downwards. Vultures perform this feat (in soarable air) by means of a wing adjustment described by one of us elsewhere.[10] In view of the high speeds obtained in soaring flight, as compared with the speed obtainable by flapping, it is probable that this power of checking speed is possessed by all soaring animals. Perhaps some of the wrist movements of pterodactyls were employed for this purpose.

The complication of the wrist movements of pterodactyls shows strikingly that the study of animal flight is a complicated problem that we can only hope to understand fully when we know more than we do at present of the nature of bird flight and especially of soaring flight.

Our illustrations have been drawn by Mr. G. Howard Short, to whom we are greatly indebted, from specimens preserved in the British Museum (Natural History) at South Kensington.

[10] "Animal Flight," p. 121.

WING ADJUSTMENTS OF PTERODACTYLS.

BY G. HOWARD SHORT.

In view of the very interesting information about pterodactyls contained in the foregoing paper by Dr. Hankin and Mr. Watson it will be worth while to endeavour to reconstruct the animal and to ascertain as far as possible the effect of the various adjustments upon the shape of the membrane which forms the wing.

This can best be accomplished by a study of the drawings accompanying this paper.

In the first place, it is important to remember that the wing membrane (plainly visible in some of the smaller fossils) doubtless resembled that of a bat in being extremely extensible and elastic. Possibly it had muscles attached to it which could tighten it in various directions and possibly increase and diminish camber. Air pressure upon this membrane would be certain to make the back margin of the wing a curved line with the convexity upward and the front margin of the wing (formed chiefly by the supporting bones) would have to follow this curved line more or less closely, otherwise the angle of incidence would vary excessively in different parts of the wing. That is to say, it is probable that the wings were arched as are those of the gull and the albatross, and, as shown in the previous paper, it is likely that the pterodactyl had a general resemblance to these birds both in flight and habits.

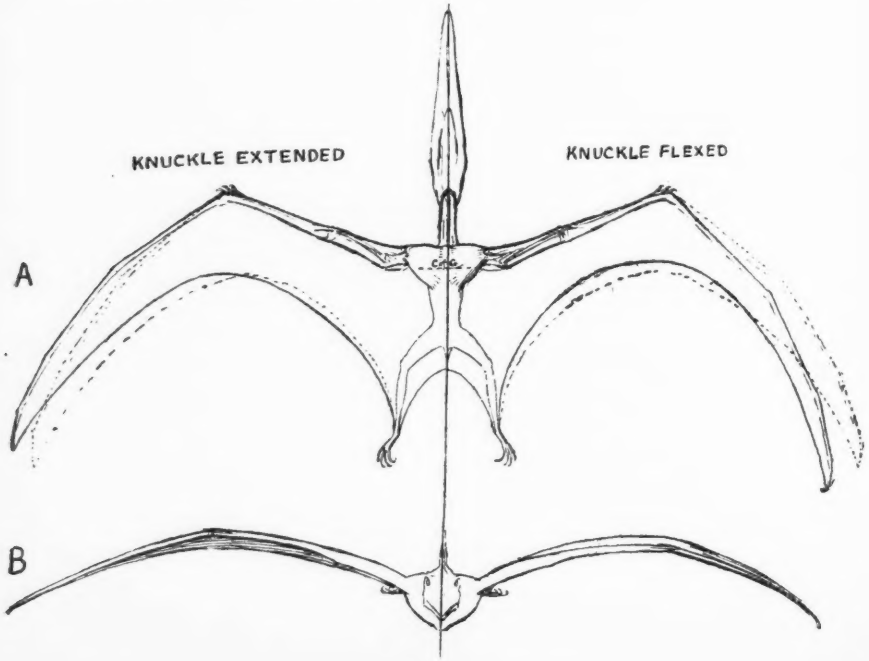

FIG. 1.

The broken lines in the plan view, shown in Fig. 1, indicate what was probably the normal gliding—and perhaps also the normal soaring attitude.* Air pressure upon the membrane would probably produce a cambered section throughout the wing, but the construction of the wing as we know it would admit of the region of the knuckle joint being at a larger angle of incidence than the rest, and a glance at the figure will show that this would introduce a variety of the longitudinal dihedral principle capable of rendering the wing stable. Reasons for believing that the wings were normally somewhat flexed have already been given in the previous paper.

It is obvious that the membrane of the wing is kept taut chiefly by means of extending the knuckle joints and, conversely, air pressure upon the membrane would tend to flex the knuckle and so impose a very powerful strain upon the knuckle extensor muscle. The strain would be multiplied, *i.e.*, the strain on the muscle would be greater than the actual pressure upon the membrane, but this multiplication would be less if the wings were strongly arched after the manner of a gull. Therefore it is probable that the arching was considerable in the ordinary gliding attitude.

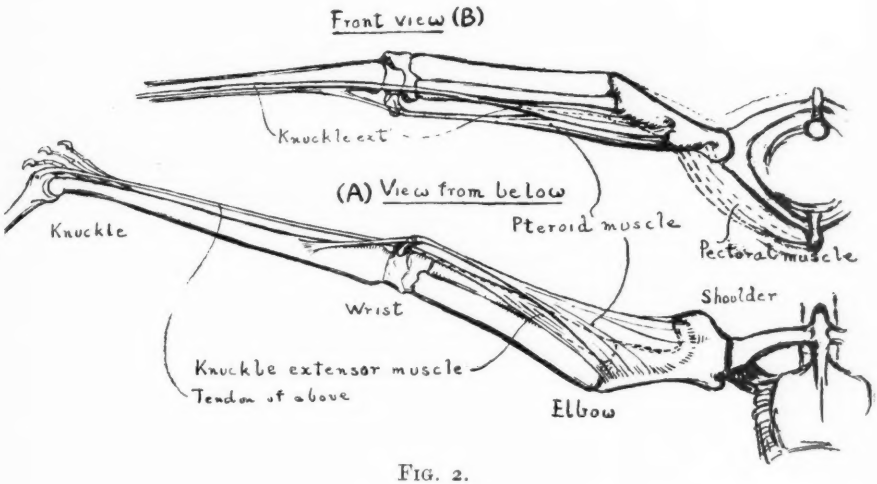

FIG. 2.

The knuckle joint was almost the only means of folding the wing and the range of movement of which it was capable must have exceeded 80°. The knuckle extensor muscle would therefore have to be capable of a large range of pull besides being of very great strength. This appears at first sight to necessitate a long fibred muscle of great bulk.

However, it seems to be more likely that this muscle was attached to the humerus in the manner shown in Fig. 2, in which case extension of the elbow would pull the muscle and by so doing extend the knuckle joint. Thus the range at the elbow joint is 30°, which might produce a movement of as much as 40° at the knuckle joint, and contraction of the muscle itself might be capable of producing another 40° or more of movement, thus accounting for the total range

* Dr. Hankin's observations upon vultures show that the attitude of soaring in "highly soarable air" differs from that of ordinary gliding in that the wings are more advanced, so that the centre of area is level with the centre of gravity. I have observed, however, that this advancement is less noticeable in the case of sea birds.

of movement. If this were so, the length of the muscle fibres could be reduced by half—so reducing the bulk by half without reducing the strength, We should thus have a muscle of small bulk capable of resisting a severe and continuous strain without fatigue.

Now we will consider the effect of air pressure upon the wing in relation to the remaining joints. In birds and bats the shoulder is a universal joint. In the larger pterodactyls it is a simple hinge admitting of up and down flapping movement only. In birds the elbow joint has a vertical axis. In the pterodactyl the axis of this joint is nearly horizontal. When looking at the plan views here shown it should be remembered that the outer part of the wing moves nearly up and down at the elbow joint, there being very little movement in the plane of the picture. (See A in Figs. 1, 2 and 3.)

When the animal was gliding the wings were held in position at the shoulder by means of large pectoral muscles (indicated in Fig. 2, B). These muscles also produced the down stroke in flapping. We are obliged to assume that there were also smaller muscles in the back of the shoulder for raising the wing. In gliding the pectoral muscle fixed the shoulder, but the wing could still bend upward at the elbow. In the previous paper it is shown that upward bending at the elbow produced downward rotation (in the direction of reduced or negative angle of incidence) together with advancement and slight upward movement at the wrist joint. It is easy to see, therefore, that air pressure from beneath would help nearly all these movements and put a severe strain on the muscles which checked the upward movement at the elbow. These muscles might have been the pteroid and knuckle extensor.

If the pteroid bone was an ossified tendon it proves that it was subjected to a very great strain, and if the pteroid muscle were attached to the humerus in a manner somewhat similar to that of the knuckle extensor (see Fig. 2) raising the wing at the elbow would put it and the knuckle extensor into tension and by this means the upward movement would be checked. The pteroid was probably a muscle of the same type as the knuckle extensor, *i.e.*, of great strength, but of small bulk and with small range of pull.

It is obvious, however, that the upward movement of the wing at the elbow joint would not be checked until the above mentioned muscles had produced the full effect of which they are capable upon the outer part of the wing. For instance, the knuckle extensor would first of all extend the knuckle and so stretch the wing membrane until the strain on the muscle balanced the pressure upon the membrane, and then the upward movement at the elbow would be checked because the muscle would not give any more. The strain would be nearly constant. Extending or contracting the muscle would only alter its length and probably affect the elbow joint mostly. However, there were doubtless other muscles at the elbow that could take a part of the strain when it was required to slacken or tighten the muscle for an adjustment

The effect of the knuckle extensor was therefore automatically to stretch the wing membrane when air pressure from below was present. But as explained above, air pressure would also pull the pteroid and the automatic effect of this muscle would be as follows:—

In flight air pressure was exerted upon the membrane which in turn transmitted this pressure to the supporting bones in an altered direction. The pressure upon the outer part of the wing was therefore felt at the wrist joint as a bending and twisting strain upon the metacarpal bone. That is to say, the distal end of the metacarpal would tend to move upward and backward and the bone would also tend to rotate downward around its large axis. The pteroid was attached to the distal carpal (which may be regarded as forming practically one mass with

the metacarpal) by means of a process which formed a lever, and the pull of the pteroid upon this lever would exactly balance the above mentioned bending strain of the air pressure and convert it into compression at the joint.* This compression would tend to rotate the metacarpal bone upward around its long axis, whereas air pressure, as above stated, tends to rotate it downward. Thus both the bending and twisting strain would be balanced and converted into compression of the joint, which would tend to increase the strength and rigidity.

The above described arrangement would automatically tighten the membrane and render all the joints sufficiently rigid as soon as the animal was in the air. This arrangement seems probable because it is economical of muscular strain, and this economy was necessary in an animal that must have spent the greater part of its existence in the air, in that it was so ill-adapted for movement upon the earth or in water.

The arrangement here described might be objected to on the following ground. The constant pull on the muscles mentioned must have put a severe strain on the ligaments of the elbow and shoulder joints as the humerus and forearm met at an angle in the horizontal plane, whereas the axis of the elbow joint was nearly horizontal. Air pressure would give no assistance in increasing this angle and the tension of the muscles would tend strongly both to reduce it and to strain the ligaments at the bend of the elbow. This objection is ill-founded, in that the large projection on the front portion of the head of the humerus very probably formed a strong lever for attachment of the anterior ligaments of the shoulder joint. These ligaments must have been directed inwards and found their insertion in some position proximal to the joints. They would not have interfered with the action of the joint and at the same time would have prevented the elbow from moving backwards (see Fig. 2, A). The forward pull of the muscles on the distal end of the forearm would then be balanced by the backward pull of the wing membrane, and all bending strain upon the elbow would be eliminated. There is no reason why the ligament at the shoulder should not have been of immense strength, amply sufficient to withstand the great strain to which it was exposed.

We will therefore use the above scheme as a basis in endeavouring to ascertain the effect of wing adjustments.

Fig. 1 shows the effect of slackening and tightening the membrane by means of movements at the carpal joint. It will be seen that this movement chiefly affects the angle of incidence. It should be remembered that there was no power or rotation at the shoulder and that rotation at the carpal joint was inseparably connected with certain other movements. Therefore if the animal wished merely to change the angle of incidence of one wing, as compared with that of the other, it would probably use this method. The legs might possibly have been used also for stretching or relaxing the membrane, but their muscles appear to have been weak.

Fig. 3 shows the effect of the automatic connection between the elbow and the wrist. The right hand side shows the extreme degree of advancement of which the wing is capable. The shoulder joint, it will be remembered, does not allow of advancement or retirement, the elbow only admits of slight advancement, while at the wrist advancement is inseparably connected with downward rotation

* It is difficult to find a reason for the joint between the lateral carpal and the distal carpal. Dr. Hankin suggested to me that it might have moved in such a way, when the pteroid was tightened or slackened, as to prevent the angle of entry at the front edge of the propatagium from altering. Slight rotation was possible between the distal carpal and the metacarpal and probably the pteroid tendon was continued on to the under surface of the metacarpal as shown in the figure, in which case pulling the pteroid would produce slight downward rotation at this joint and the lateral carpal would move slightly upon the hinge joint by which it was attached to the distal carpal.

XUM

(reduced angle of incidence) of the portion of the wing that is advanced, namely, the wing front.

Thus the pterodactyl could not produce a powerful upwardly rotating couple between lift and weight by advancing its wings, as the downward rotation of the wing tip would counteract the effect of the advancement which in itself is slight. This is in great contrast to the almost unlimited power of advancement and simultaneous upward rotation of the wing tip possessed by birds and to a lesser extent by bats. It is also remarkable in view of the statement in the foregoing paper to the effect that the bones of large pterodactyls were so fragile that they would probably break if the animal endeavoured to flatten out suddenly after a dive. Apparently the pterodactyl's power of producing a sudden upward rotation was specially restricted. It could doubtless rotate itself up somewhat gradually

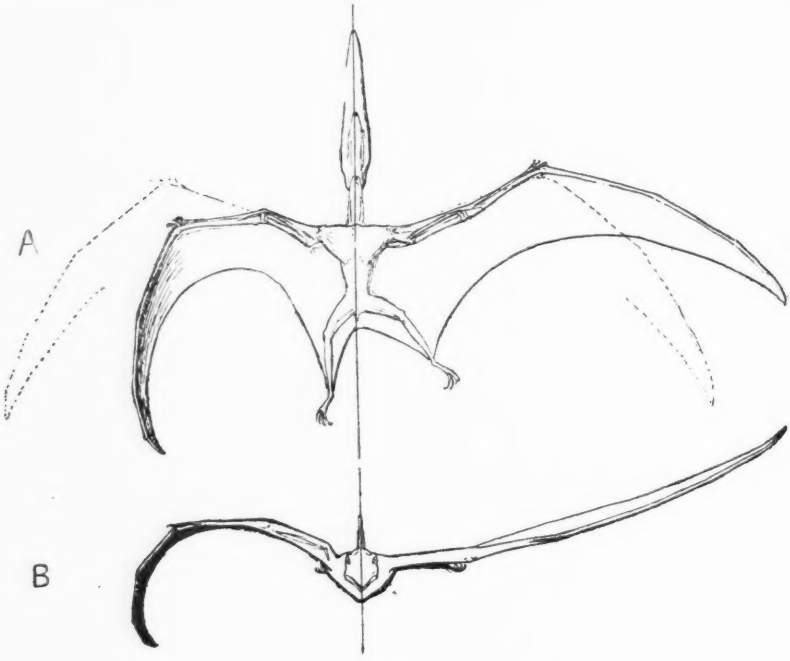

FIG. 3.

by pulling the pteroid powerfully with wings at a lesser degree of advancement or by some other means such as placing the wings dihedrally up and increasing the drag at the wing tip. It is also a remarkable fact that extending the wing fully would, by stretching the back margin, tend to make it straighten and so produce tension along the chord of the wing and increase the breadth of the elastic membrane, consequently the area of the wing would be increased. But tension along the chord would certainly reduce the camber so that in the pterodactyl increase of area was connected with reduced camber, whereas in all birds increase of area is connected with increased camber, and the latter seems the most natural combination.

If the pterodactyl wished to retire its wings it could do so by flexing the elbow as shown (both in plan and end-on view) in the left hand side of Fig. 3.

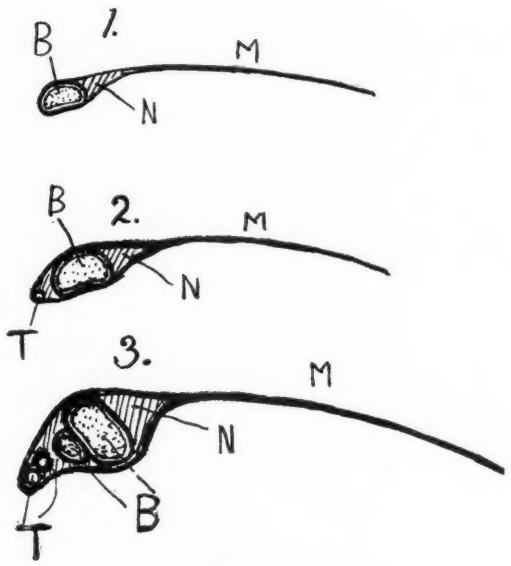

FIG. 4.

PROBABLE WING SECTIONS OF A LARGE PTERODACTYL.

1. MIDDLE OF FIRST WING PHALANX.
2. MIDDLE OF METACARPAL.
3. MIDDLE OF FOREARM.

B BONE. T TENDON. N NERVES, BLOOD VESSELS, SMALLER MUSCLES, ETC.
M MEMBRANE OF WING.

FIG. 5.

PTERANODON GLIDING AND ABOUT TO COMMENCE A FLIGHT.

Fig. 4 shows the probable shape of the wing sections of a large species of pterodactyl. They are apparently somewhat clumsy in the neighbourhood of the leading edge. This need not indicate inefficiency in soaring flight, as Hankin has discovered that many of the most efficient soaring birds have wing sections of apparently clumsy shape.* It is therefore rather an additional argument in favour of the supposition that these pterodactyls spent the greater part of their active existence in soaring flight.

Fig. 5 is an attempt at a complete restoration of the species pteranodon in the normal gliding position and also when about to commence a flight by jumping from the edge of a cliff. It is probable that they started usually by jumping from some high object and possibly they resembled certain birds in not being able to rise from flat ground.

It should be remembered that although the wings could doubtless be used for support on the ground, as shown in the figure, the animal could not walk with them as there was no power of fore and aft movement at the shoulder and practically none at the elbow, while the movement at the carpal joint in this direction was for the most part automatically connected with movement at the elbow.

The most feasible way in which it could have alighted appears to be as follows:—After gliding along with speed gradually decreasing and angle of incidence increasing, owing to adjustments described above, the speed would be abolished within about two feet of the ground; then it would suddenly flex its wings, throw forward its legs, and alight in an attitude somewhat similar to that shown in the illustration. It may be suggested that it might have always alighted upon the water, but this is improbable, because it is doubtful whether it could have risen again from that element.

The long flat crest is a characteristic feature of pteranodon, but it was not present in other large pterodactyls, and is therefore of no indispensable import, although the effect of air pressure upon it is perhaps not altogether negligible. It might even have been useful in steering the animal round to the right or left when it turned its head in either of these directions, but it is possible that it was chiefly ornamental in character. *(See remarks below.*—ED.).

The illustrations show practically all the adjustments of which the wings were capable except a possible change of camber or angle of incidence caused by upward or downward movement of the legs. This is anatomically possible and might have been used. On the whole the wings are remarkably stiff as compared with those of birds and bats, although every consideration points to the probability that these large pterodactyls were highly efficient when in the air and probably possessed the power of soaring flight in a high degree.

This paper is an attempt to show how the soaring attitude could have been maintained and the wing adjustments carried out with the minimum of muscular exertion. It is possible to make guesses as to the means adopted for steering or changing camber, preserving balance, etc., but it is not in these cases always possible to decide between different alternatives. Further knowledge of the soaring flight of sea birds rather than of land soaring birds may be expected to throw light on the subject.

[NOTE.—There is evidence throughout the animal world, and notably amongst flying animals, of large and cumbersome adornments being carried about by their possessors for apparently no other reason than that of captivating the opposite sex during the breeding season (*e.g.*, the tail of the peacock). But in the cases

* See "Animal Flight," Chapter XIX.

that spring readily to the mind all these additions have either some "survival value" themselves, or are not detrimental to the survival value, as a whole, of the animal of which they form part. In the case of Pteranodon, however, it would appear that it was so highly specialised for flight that any addition of the size and character of the crest which it actually possessed could not fail to modify very considerably its mode of flight and consequently its "survival value." In other words, it is obvious that a flying animal that has cut down weight in all other directions is most unlikely to have evolved a large crest either at the expense of, or without effect on, its flying capabilities. That is to say, the crest must have been of aerodynamic advantage to its possessor before its evolution could have progressed nearly as far as it did. It is not difficult to see that such a crest could have been very useful from the point of view of stability. Those who are familiar with the extreme importance of fin disposition on the stability of aeroplanes will not need to have it pointed out that whenever Pteranodon pointed its beak downwards it moved a large fin area backwards and downwards. It could correct for this by wing or "tail" movement, or by bringing into play a corresponding fin area that moved forward and upward. Such a fin area was its "crest," and its action would be automatic as the head rotated round its attachment to the neck. It is clear that, should it have been necessary for Pteranodon to possess a larger fin area than its actual bony crest, an elastic membrane could have existed between the crest and the back of its neck, giving a variable fin area as the crest moved.

We do not know what were the characteristics of the flight of Pteranodon which differentiated it from that of other pterodactyls. We can say, however, that if the latter had a large beak like Pteranodon, but no crest, they either flew in such a manner or in such places that fin area was unimportant between wide limits of movement, or they corrected for its movement by wing or "tail" action that presumably was beyond the scope of Pteranodon.

It would be interesting to have a critical comparison, from the above point of view, of such of the remains of pterodactyls as we possess.

EDITOR, AËRONAUTICAL JOURNAL.]

ATMOSPHERIC ROTARY MOVEMENTS OF SMALL EXTENT.

BY DR. E. H. HANKIN, M.A., A.F.AE.S., F.R.MET.SOC. (AGRA, INDIA).

A short summary of our knowledge of this subject may be of interest to readers of the AËRONAUTICAL JOURNAL.

Dust devils.

Dust devils, that is to say, columns of dust in rapid rotation, are occasionally seen in Agra. They only occur in hot, dry weather. Those of the largest size, having a diameter of two or three metres and a height of several hundred metres, only occur when the air is nearly calm. They travel to leeward at a speed of about four to six miles per hour. The dust, having reached the upper end of the column, spreads out into a diffuse, irregular mass, which may persist for some time after the dust devil that produced it has vanished.

Fig. 1 is copied from a book treating of dust devils and dust storms observed at and near Lahore (India) by P. F. H. Baddeley.[1]

He states that they are never shaped like an inverted funnel, as is the case with whirlwinds in America, as described by Redfield.[2] On the contrary, in some cases they retain a uniform diameter of ten or twelve inches while reaching a height of several thousand feet. Their long axis may be vertical and perfectly straight, as in the figure reproduced. Or the long axis may be straight, but bent over in the direction of the wind. Or the long axis may be curved, and in one case figured by Baddeley it is recurved on itself, forming a loop of the same shape as the track of an aeroplane while "looping the loop."* This latter case must indicate the presence of wind irregularities, which must be absent in the former and more usual examples

Baddeley says dust devils are common in all parts of India during the dry season.[3] They are most numerous in February, March, April, May, and June. They cease for the most part during the rains (July, August, September) and reappear in the cold, dry weather of the winter months. They begin to develop three or four hours after sunrise and continue till three or four o'clock in the afternoon. Thousands may be seen during the six or seven hours following their commencement. They are most numerous about midday. They are rarely noticed after sunset or at night.[4]

Perhaps the most extraordinary fact observed by Baddeley is that dust devils sometimes show a sudden reversal of the direction of their rotation. In

[1] P. F. H. Baddeley, "Whirlwinds and Dust Storms of India." (London: Bell & Daldy, 1860.) (British Museum Library, No. 14000.7.12 and 8756.d.1.)

[2] W. C. Redfield, "On the Spirality of Motion in Whirlwinds and Tornadoes." *London and Edinburgh Philosophical Magazine and Journal of Science*, Vol. XIII. (Fourth Series), January-June, 1857, p. 223. (British Museum Library, No. RPP.61.1433.)

* In the rooms of the Royal Meteorological Society, London, is an old print showing a group of waterspouts. One waterspout is shown twisted into a loop similar to that of the looped dust devil mentioned and figured by Baddeley.

[3] They are far less common in Agra than they are in the Punjaub and Rajputana. In the damp climate of Calcutta they are small, transitory, and infrequent.

[4] Unfortunately, Baddeley's account is coloured by a theory that dust devils were due to "spiral threads of electro-magnetic fluid," and that they were of the same nature as dust storms. Dust storms occasionally occur after sunset. It is extremely unlikely that real dust devils have ever been observed at this time.

one instance he observed several such changes in one dust devil within two or three minutes. That is to say, a dust devil in which the rotation is clockwise may suddenly arrest its movement and then begin to rotate in counter-clockwise direction. Fortunately, it is possible to quote independent evidence as to the occurrence of this surprising phenomenon.

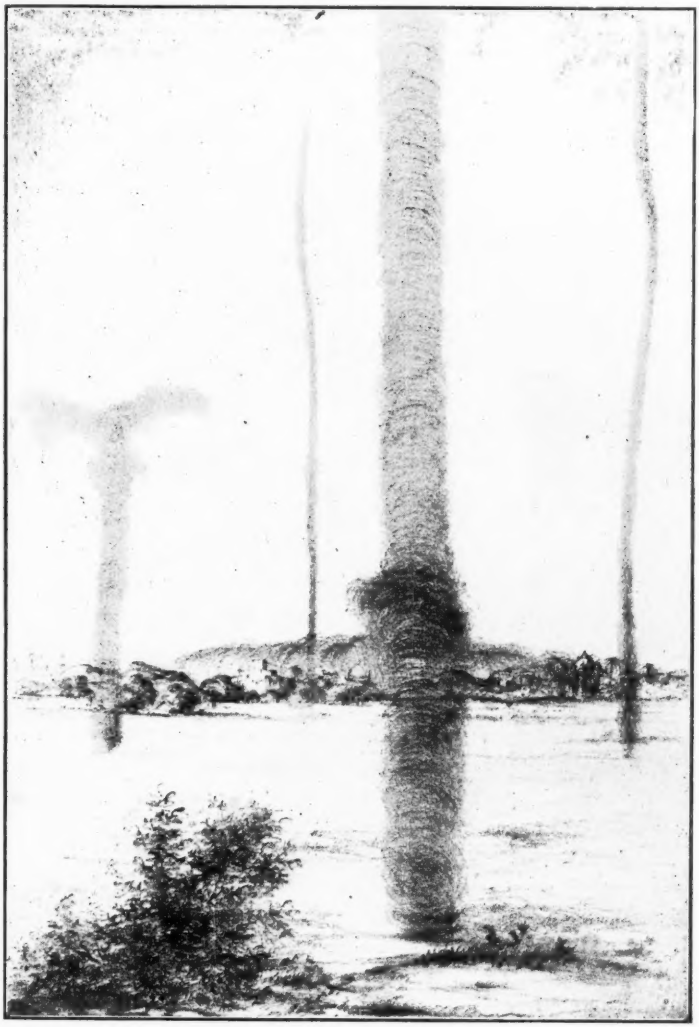

FIG. 1.—DUST DEVILS, AFTER BADDELEY.

Dr. Alfred Wegener has observed dust devils on the lava-covered plain of Odadahraun in Iceland.[5] The black lava dust, he states, is well adapted to

[5] Alfred Wegener, "Staubwirbel auf Island," *Meteorologische Zeitschrift*, April, 1914, Pt. 4, Vol. XXXI., p. 199.

absorb the heat of the sun's rays, and so to give rise to ascending currents. From the colour of the dust, the dust devils when formed are easily visible. At the time of his visit to Odadahraun there was a calm at ground level and a wind of 5 m.p.s. at a height of 30 metres. There were small isolated strato-cumulus clouds with patches of blue sky. The dust devils were of about 100 metres height and of 5 to 10 metres radius. Sometimes twenty to thirty were visible at the same time. He noticed a dust devil that was rotating to the right, after a short internal disturbance, to suddenly change its direction of rotation and begin turning to the left. He also noticed irregular masses of dust rising to the same height as the dust devils. Sometimes the rising dust was visible over a large area, giving the appearance of smoke rising from the ground. Portions of this rising dust sometimes showed traces of rotary movement. Some rotating whirls were seen to suddenly fuse to form a dust devil.

To return to Baddeley's description. He says: "The smaller whirlwinds possess an independent power of motion; are liable to sudden augmentation or diminution in their rotative energy and ascensive force; have been observed to change their direction suddenly without apparent cause; and also to expand and divide into separate columns, like the strands of a rope before they are cut off, and unite again; and, what seems most unaccountable, to reverse the rotation instantaneously when whirling most rapidly. . . . They turn indifferently from left to right or from right to left, and their rotary motion sometimes seems suddenly reversed, though that may be only an optical illusion."

In order to explain the causation of dust devils it is necessary to study other forms of rotary movement observed in the air.

Tornadoes are whirlwinds occurring singly and of very large size and destructive effect. One account of a tornado says: "Its first condition was undoubtedly that of a simple whirlwind, having a diameter of about 1,000 feet, which uprooted or twisted off nearly every tree in its circle, etc." [6] According to another account: "The cloud formation was of the typical funnel type, seemingly about 600 feet high with the point touching the earth." [7]

Ferrel's theory of Tornadoes.

A theory of the nature of tornadoes has been put forward by Ferrel.[8] It is briefly that air near the earth becomes heated by the sun's rays and tends to rise. If the air at a height has not been proportionately warmed, then at any point a strong ascending current of air may be formed. Heated air is thereupon drawn in from all sides towards this centre. If, as is practically certain to occur, this air does not all follow precisely radial lines, a whirl must necessarily be produced. An increase of speed of the whirl as the centre is approached must occur, for the reason illustrated in *Fig.* 2. Let us imagine that the spiral lines A and B each represent the track of a particle as it travels towards the centre of the whirlwind. A particle at the point A after a certain time reaches the point A′. A particle at B in the same time reaches the point B′. The air included between A and B after the lapse of this time is included between A′ and B′. That is to say, the air between the two spiral lines is travelling in a track which is constantly narrowing. Its speed must accordingly increase. As explained by Davis: "This increase of velocity of the surface indraught toward the point of its upward escape is a general feature of the motion of a mass of free particles along a path of varying width; the narrower the path the faster the

[6] W. Ferrel, "A Popular Treatise on the Winds" (John Wiley & Sons, New York, 1889.)

[7] A. C. Arend, "The Effect of the Omaha Tornado on Structures," *Engineering News* (New York), 1st May, 1913, Vol. LXIX., No. 18, p. 898.

[8] Ferrel, loc. cit.

motion." [9] It may be noted that a necessary condition for the increase of speed in a whirlwind is that the air should be removed as it approaches the centre. This occurs owing to the upward current to which the whirlwind is originally due. The stronger the upward current the greater will be the speed of rotation. In the case of the tornado the speed of rotation is so high that centrifugal force causes a reduction of pressure at the centre of the whirl. If a tornado passed over a perfectly smooth surface, all that would be seen would be a large whirlwind with a hollow transparent centre. The hollow appearance would be due to all solid particles having been removed from the region of the axis of the whirl by the action of centrifugal force. But, as a matter of fact, owing to friction with the surface of the earth, air near ground level cannot participate in the rotary movement to the same extent as air at some height above ground level. Hence, according to Ferrel, air at low level is not subjected to the same extent to the centrifugal tendency. It accordingly rushes inwards to fill up the vacuum or partial vacuum in the centre of the tornado. It is this air rushing towards the centre that causes the strong winds to which the destructive effects are due.

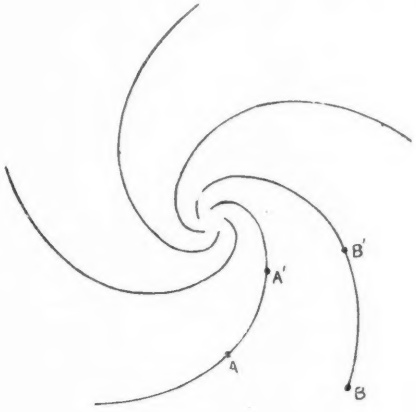

FIG. 2.

In conformity with Ferrel's theory, a hollow core has been seen in the centre of the most destructive tornadoes. In other words, the axis of the whirlwind was freed in these cases from solid objects by the intense centrifugal force caused by the rotation. A similar transparent core has been observed in whirlwinds, and also in waterspouts, as recorded by Benjamin Franklin in 1756.[10] I have on one occasion seen a transparent central core in a dust devil.[11] With regard to waterspouts, I may quote the following observations from my diary :—

> 22nd December, 1912. Near Middle of Red Sea. 7.0 a.m. A hollow tube of cloud matter seen to descend from the under part of the centre of a flat-bottomed cumulus cloud. After a few minutes the tube broke up, the breaking beginning from below. The separated masses of cloud matter (*i.e.*, those derived from the walls of the lower part of the breaking up tube) were seen to travel up the lumen of the upper part of the tube that was still intact. A few minutes later another waterspout formed and showed the

[9] W. M. Davis, "Whirlwinds, Cyclones, and Tornadoes." (Boston : Lee & Shepard, 1884.)
[10] "Benjamin Franklin, Works of," edited by Bigelow, Vol. II. (Putnam & Sons, New York and London, 1887, p. 267, Letter XCV. to John Perkins, read at Royal Society of London, 24th June, 1756.)
[11] "Animal Flight," p. 277.

same phenomenon when breaking up. No trace of commotion was seen on the sea below, but the cloud was so far away that if there was any such disturbance it must have occurred beyond the horizon.

According to my recollection, the long axis of both of these waterspouts appeared to be vertical during the whole time they were under observation.

Production of Whirlwinds by artificial ascending currents.

If tornadoes and whirlwinds are primarily caused by ascending currents of air, then one might expect the ascending current of air produced by a large fire to cause a whirlwind. Some cases of this occurring have been studied and recorded by Mr. W. C. Redfield, the American meteorologist, to whose work our knowledge of cyclones is principally due. I give the following extracts from his paper on the subject [12] :—

(1) At Stockbridge, in Massachusets, in April, 1783, the season had been very dry, and many spontaneous fires had occurred in the woods. At a time when the air was calm a heap of dry brushwood was set alight. A whirlwind formed in the midst of the flames. It appeared as a pillar of fire reaching to a height of 200 feet. It moved slowly round the field. The power of the whirlwind was so great that young cut trees lying on the ground with stems six or eight inches in diameter were lifted to a height of forty or fifty feet. The men who had set light to the field were so frightened that they fled to a neighbouring river for safety.

(2) In the year 1830, at Greenbush, near Albany, brushwood from an area of twenty-five acres had been cut and prepared for burning. To prevent spreading of the fire the part lying near the outskirts was moved inwards, forming a circular heap round the general mass. On a warm and perfectly calm summer's day the circle was fired on all sides nearly at the same time. The smoke and flame soon gathered towards the centre, where they whirled and ascended in great rapidity in a single column, " attended with a loud, roaring noise, and a sort of crackling and nearly continuous thundering resembling that which I have heard in a violent hail storm." The whirlwind continued for about twenty minutes. The height of the smoke column was as great as the eye could reach, according to Mr. W. Akin, who furnished this account.

Redfield quotes other similar cases. He points out that even the largest fires cause no draught sufficient to raise heavy weights in ordinary cases. This, however, occurs in those cases in which a whirlwind is produced. He thinks the circular outline of the fire and the absence of wind contributed to cause the formation of the whirlwind in the above instances. Smoke from a large fire only ascends to a moderate height. If a whirlwind is formed, much greater heights are reached. He considers the above example to be analogous to violent columnar whirlwinds that have been observed to form over the craters of active volcanoes.

A still more interesting case has been recorded by A. F. Olmsted.[13] He has given a description of the burning of a cane brake at Tuscaloosa, Alabama, on the Black Orange River. The fire extended over an area of twenty-five acres. There was much noise from the bursting of the canes, but no thunder or sign of electrical disturbance, as has been stated to occur in other cases.

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[12] W. C. Redfield, " Some Account of Violent Columnar Whirlwinds which appear to have resulted from the action of Large Circular Fires." *American Journal of Science and Arts* (Silliman), Vol. XXXVI., July, 1839, p. 50. New Haven. (British Museum Library, No. RPP. 1435.)

[13] A. F. Olmsted, " Whirlwinds Produced by Burning of a Cane Brake." *American Journal of Science and Arts,* Vol XI., 1851, p. 181. (British Museum Library, No. RPP. 1435.)

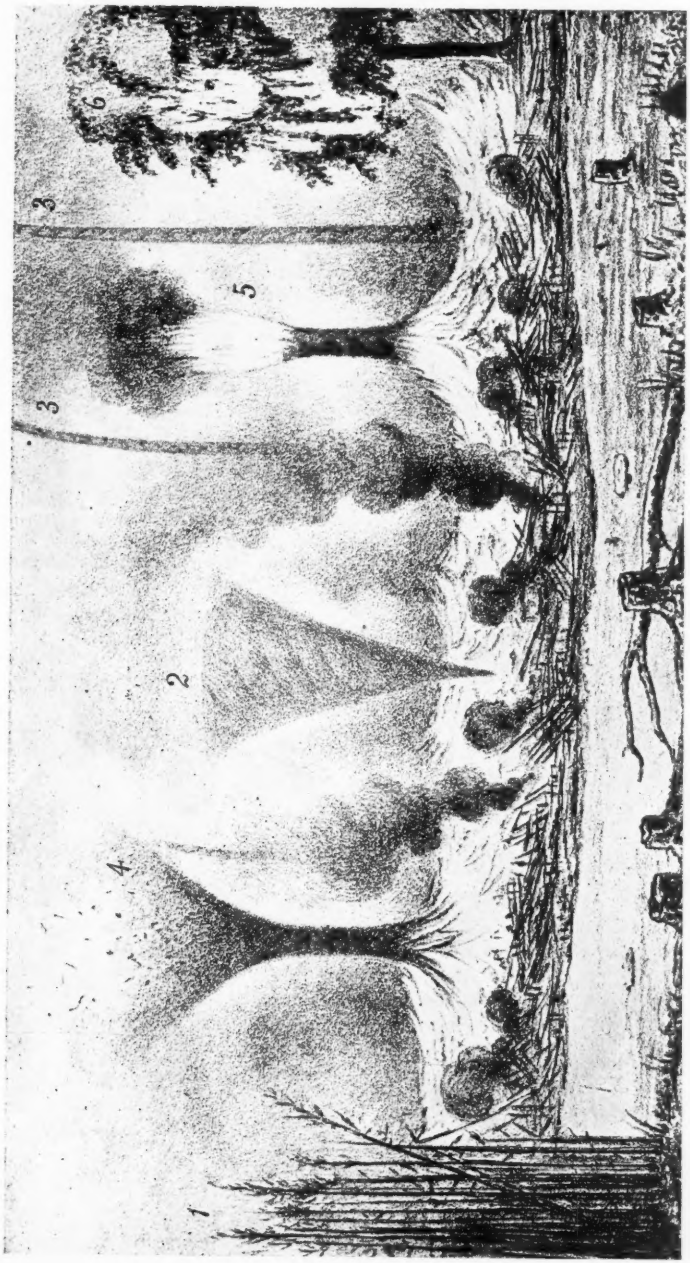

FIG. 3.—WHIRLWINDS CAUSED BY BURNING OF A CANE BRAKE, AFTER OLMSTED.

Many whirlwinds were formed at the same time. They were of different kinds, and are illustrated in the accompanying figure from Olmsted.

No. (4) was the most common form. It remained stationary, and appeared to form over a part of the fire that was hotter than neighbouring areas.

No. (2), shaped like an inverted funnel, had a progressive motion. It generally occurred over ashes, "being formed in the air above." Towards the end of the conflagration several large whirlwinds of this pattern were formed. They moved about spinning like tops, dispersing the ashes below them, but only taking up small quantities of the ashes that came under the points of their cones.

No. (5) was formed on a pile of burning cane. At its central portion flame was extinguished, leaving only a column of smoke, which again burst into flame above. The greatest velocity of movement was shown in this dark area, which area varied in size.

No. (3) is of interest, in that it is shaped like a dust devil. These were often several hundreds of feet high. Towards the top they were sometimes bent over by the wind. These fire dust devils, and also pattern No. (2), were most common when the fire was dying down.

Olmsted says: "The whole mass of the air after entering the area above the fire exhibited a tendency to rotary motion, being full of eddies and whirlwinds."

The whirlwinds revolved in either direction, but "frequently the same whirlwind would change the direction in which it revolved and would return to its first course. In a few instances this was repeated several times. This never happened with pattern No. (2)."

Thus the reversal of direction of rotation of dust devils observed by Baddeley in India and Wegener in Iceland has been seen in the fire dust devils artificially produced.

Olmsted says that in this instance whirlwinds only became frequent and large when the fire had become circular and of large size. Olmsted makes the curious statement that the circular fire used in putting a tyre on a wheel sometimes gives rise to whirlwinds of fifteen to twenty feet height. This occurs especially when the fire is in a sheltered courtyard. The whirlwinds produced may be of any of the above described types.

According to Davis,[14] the artificial production of whirlwinds attracted much interest when first published, as it was hoped that they might be used for the production of rain. If it were practicable to make whirlwinds on a sufficiently large scale, one might expect them to be of use in removing unstable atmospheric conditions rather than in causing a fall of rain, but I can find no record of experiments in either direction having been attempted.

Some kind of electrical discharges appear to have accompanied the larger artificial whirlwinds. A way to an explanation of such phenomena is offered by the work of Rudge [15] on electrification produced by raising of dust. His discoveries also point to an explanation of the electrified state of the air that has been observed, by Baddeley and others, during dust storms.

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[14] Loc. cit., p. 10.

[15] W. A. Douglas Rudge, "On the Daily Range of the Atmospheric Potential Gradient at Bloemfontein, and the Influence of Dust Storms." Transactions of the Royal Society of South Africa, Vol. IV., Part I., 1914, p. 75; and "On the Electrification Produced during the Raising of a Cloud of Dust." Proceedings of the Royal Society of London, A, Vol. XC., 1914, p. 256.

Waterspouts.

Another form of rotary movement remains to be mentioned, namely, the waterspout.

Whereas dust devils only occur during the daytime, and in sunshine, and generally, at least, commence at the surface of the earth, waterspouts always begin on the under side of a cloud, and may occur at night. Baddeley gives an account of twenty-five waterspouts being seen within four hours at night, having been rendered visible by lightning flashes.

Benjamin Franklin suggested that waterspouts might have their origin in a descending current of air. A local descent of cold air might be imagined to result in a rushing of air from all directions towards the centre of the current, which rushing might initiate a rotary movement analogous to what occurs in the case of a dust devil.

Wegener's Theory.

Recently Wegener has suggested another theory of the nature of waterspouts.[16] He states that waterspouts are never vertical in direction. The inclination of their axes from the vertical shows no relation to the strength or

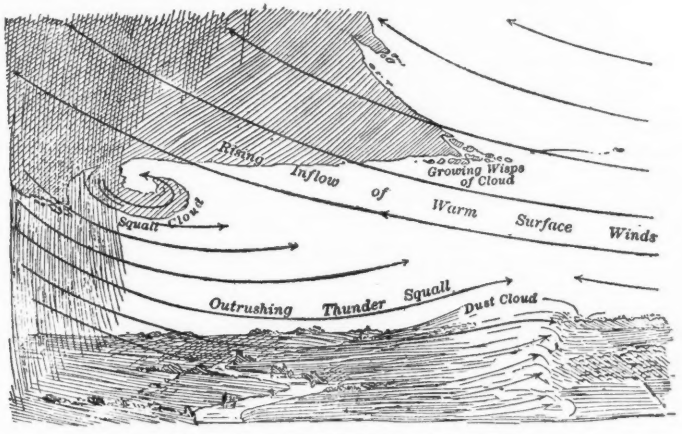

FIG. 4.—DIAGRAM OF THUNDER SQUALL, AFTER DAVIS.

direction of the wind. They are most frequently found at the sides of storms. He regards a squall (especially one occurring in advance of a thunderstorm or rain storm) as being part of a whirlwind having a horizontal axis. This axis is supposed to be at right angles to the advance of the storm. He supposes that waterspouts are the turned-down ends of such horizontal whirls. If this theory is true, a waterspout occurring on the left-hand side of a storm should rotate in a counter-clockwise direction, while one occurring on the right side should have clockwise rotation. Observations to elucidate this point have not yet been made, though he quotes one case in which a left side waterspout was observed to be rotating in the direction required by his theory.

[16] A. Wegener, "Ueber den Ursprung der Tromben." *Meteorologische Zeitschrift*, May, 1911, Vol. XXVIII., p. 207. An account of Wegener's theory is given in the *Scientific American* of the 7th March, 1914, Vol. CX., No. 10, p. 193.

Wegener's view is elucidated by the preceding diagram (*Fig. 4*) copied from Davis,[17] representing a side view of an advancing thunder squall. It will be noticed that a horizontal whirl is shown (in section) as being formed between the "rising inflow of warm surface winds" and the "outrushing thunder squall." With regard to this Davis says: "A grey roll of cloud is generally observed at a little distance back of the lower dark cloud front; if carefully watched, it may be seen to turn slowly between the inflow above and the outflow below. Its presence seems to depend on an eddy caused by the squall, and it is therefore called the

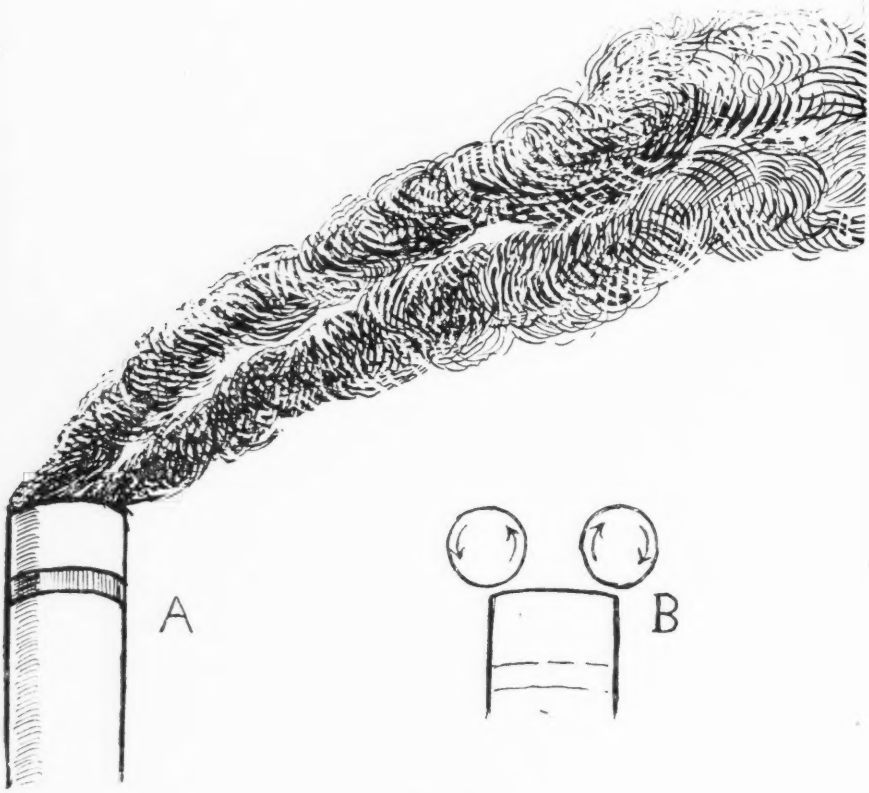

FIG. 5.

"squall cloud." If Davis's interpretation of the facts is correct, it affords direct evidence of the existence of a whirl, as postulated by Wegener. But I have failed to find any other record of observational evidence of this nature, though Arrhenius[18] gives a diagram of a thunderstorm in which the presence of a whirl at a corresponding point is indicated by arrows.

A practical point is indicated by the diagram. The cloud mass overhangs the front and sides of the storm. There is no such overhang at the back of the storm. Hence, in the case of an isolated thunderstorm, observation

[17] W. M. Davis, "Elementary Meteorology," p. 263. (Boston: Ginn & Co., 1894.)

[18] S. A. Arrhenius, "Lehrbuch der kosmischen Physik," p. 797. (Leipsig: S. Hirzel, 1903.)

of the overhang may be used to give some idea whether the storm is advancing towards or receding from the observer. If at the nearest part of the storm the cloud and the sheet of rain below extend uninterruptedly from the upper limit down to the horizon, then the storm is certainly receding. The storm may be approaching if the nearest portion of the storm shows an overhang.

Rotary movements in smoke.

Rotary movement may sometimes be observed in smoke issuing from a factory chimney or from the funnel of a steamer. In light winds, and if the steamer is travelling at slow speed, occasionally indications may be seen of the existence of vortex loops reminiscent of those illustrated in a paper by L. Bairstow, published in the AERONAUTICAL JOURNAL, Vol. XVII., facing page 122.

But if the movement of the steamer is such that the funnel has high speed relatively to the surrounding air, then occasionally an appearance may be seen illustrated in the preceding figure (*Fig. 5*).

For a fraction of a second the smoke may be seen to take the form of two whirls rotating rapidly in opposite directions and extending for several metres aft of the funnel. An observer immersed in the smoke on a level with the top of the funnel and looking towards it would see the appearance indicated at B. But this appearance of two straight whirls lasts only for a fraction of a second. The long axis of each whirl, instead of being a straight line, changes rapidly to a zig-zag. A moment later the appearance again changes, and the two zig-zag whirls seem to be rapidly swelling so that confused smoke masses reach almost up to the funnel. The appearance is as if the two whirls are constantly present, but that the axis of each whirl is constantly lengthening, while each whirl is constantly increasing in diameter at an irregular and varying rate. If one stands on a steamer and looks towards the stern always lateral portions of the mass of smoke are seen to be descending. This is seen to be the case even with smoke that has reached a position some distance astern of the ship.

I take this opportunity of expressing my thanks to Mr. W. Marriott, F.R.Met.Soc., who has given me much assistance in finding references to the literature summarised in this paper.

BRITISH FATALITIES.

Date.	Name.	Nationality.	Machine.	Place.
Aug. 12	Lieut. R. K. Skene Air Mech. R. K. Barlow (P.)	English.	80 Bleriot (1).	Netheravon.
„ 16	Lieut. E. W. C. Perry Air. Mech. E. G. Parfitt (P.)	English.	B.E.8 (2).	Amiens.
„ 18	Corpl. F. J. P. Geard (P.)	English.	B.E.8 (2).	nr. Peronne.
„ 22	Lieut. V. Waterfall ... Lieut. Bayly (P.) ...	English.	Avro (2).	nr. Enghien.
Sept. 14*	Lieut. R. T. Gates	English.	Farman (2)	Hendon.

* Date of death. Accident 10th September.

(1.) Monoplane. (2.) Biplane. (P.) Passenger.

THE ROYAL FLYING CORPS ON ACTIVE SERVICE.

The following references to the work of the R.F.C., from official despatches, are placed on record here as a supplement to the military lectures and discussions reported in THE AERONAUTICAL JOURNAL (Nos. 61, 62, 63, 67, 70). The confirmation of many prophecies made at our meetings is remarkable and gratifying.

From Sir John French's despatch 7th September:—

"I wish particularly to bring to your Lordship's notice the admirable work done by the Royal Flying Corps under Sir David Henderson. Their skill, energy, and perseverance have been beyond all praise. They have furnished me with the most complete and accurate information, which has been of incalculable value in the conduct of the operations. Fired at constantly, both by friend and foe, and not hesitating to fly in every kind of weather, they have remained undaunted throughout.

"Further, by actually fighting in the air, they have succeeded in destroying five of the enemy's machines."

From Sir John French's report dated September 11th, issued September 14th:—

"Quite one of the features of the campaign, on our side, has been the success attained by the Royal Flying Corps. In regard to the collection of information it is impossible either to award too much praise to our aviators for the way they have carried out their duties or to over-estimate the value of the intelligence collected, more especially during the recent advance.

"In due course certain examples of what has been effected may be specified and the far-reaching nature of the results fully explained, but that time has not yet arrived. That the services of our Flying Corps, which has really been on trial, are fully appreciated by our Allies is shown by the following message from the Commander-in-Chief of the French Armies, received on the night of September 9th by Field-Marshal Sir John French:—

> "'Please express most particularly to Marshal French my thanks for services rendered on every day by the English Flying Corps. The precision, exactitude, and regularity of the news brought in by its members are evidence of their perfect organisation and also of the perfect training of pilots and observers.'

"To give a rough idea of the amount of work carried out, it is sufficient to mention that, during a period of twenty days up to the 10th September, a daily average of more than nine reconnaissance flights of over 100 miles each has been maintained.

"The constant object of our aviators has been to effect the accurate location of the enemy's forces, and incidentally—since the operations cover so large an area—of our own units. Nevertheless, the tactics adopted for dealing with hostile aircraft are to attack them instantly with one or more British machines. This has been so far successful that in five cases German pilots or observers have been shot in the air and their machines brought to the ground.

"As a consequence, the British Flying Corps has succeeded in establishing an individual ascendancy which is as serviceable to us as it is damaging to the enemy. How far it is due to this cause it is not possible at present to ascertain

definitely, but the fact remains that the enemy have recently become much less enterprising in their flights. Something in the direction of the mastery of the air has already been gained.

"In pursuance of the principle that the main object of military aviators is the collection of information, bomb-dropping has not been indulged in to any great extent. On one occasion a petrol bomb was successfully exploded in a German bivouac at night, while, from a diary found on a dead German cavalry soldier, it has been discovered that a high-explosive bomb thrown at a cavalry column from one of our aeroplanes struck an ammunition waggon. The resulting explosion killed fifteen of the enemy."

Admiralty Report, 23rd September, 1914:—

"Yesterday British aeroplanes of the Naval Wing delivered an attack on the Zeppelin sheds at Dusseldorf.

"The conditions were rendered very difficult by the misty weather, but Flight Lieutenant C. H. Collet dropped three bombs on the Zeppelin sheds, approaching within four hundred feet.

"The extent of the damage done is not known.

"Flight Lieutenant Collet's machine was struck by one projectile, but all the machines returned safely to their point of departure.

"The importance of this incident lies in the fact that it shows that in the event of further bombs being dropped into Antwerp or other Belgian towns measures of reprisal can certainly be adopted if desired to almost any extent."

From Sir John French's despatch dated 8th October, 1914:—

"Sir David Henderson and the Royal Flying Corps under his command have again proved their incalculable value. Great strides have been made in the development of the use of aircraft in the tactical sphere by establishing effective communication between aircraft and units in action. It is difficult to describe adequately and accurately the great strain to which officers and men were subjected almost every hour of the day and night throughout this battle. . . .

"In my despatch of 7th September I mentioned the name of Brigadier-General Sir David Henderson and his valuable work in command of the Royal Flying Corps, and I have once more to express my deep appreciation of the help he has since rendered me."

Admiralty Report, 9th October, 1914:—

"Squadron Commander D. A. Spenser Grey, R.N., reports that as authorised he carried out, with Lieutenant R. L. G. Marix and Lieutenant S. V. Sippe, a successful attack on the Dusseldorf airship shed.

"Lieutenant Marix's bombs, dropped from 500ft., hit the shed, went through the roof, and destroyed a Zeppelin. Flames were observed 500ft. high, the result of igniting the gas of an airship. All three officers are safe, but their aeroplanes have been lost. The feat would appear to be in every respect remarkable, having regard to the distance—over a hundred miles—penetrated into country held by the enemy, and to the fact that a previous attack had put the enemy on their guard and enabled them to mount anti-aircraft guns."

XUM

Memorandum by the Director of the Air Department, Admiralty, 11th October, 1914:—

"Commander Charles R. Samson, R.N., was in command of the Aeroplane and Armoured Motor Support of the Royal Naval Air Service (Naval Wing) at Dunkerque, between the dates 1st September to 5th October.

"During this period several notable air reconnaissances were made and skirmishes took place. Of these particular mention may be made of the aeroplane attack on 4th September on four enemy cars and 40 men, on which occasion several bombs were dropped; and of the successful skirmishes at Cassel on 4th September, Savy on 12th September, Aniche on 22nd September, Orchies on 23rd September.

"On the 22nd September, Flight Lieutenant C. H. Collet, of the Royal Naval Air Service (Naval Wing of the Royal Flying Corps), flying with a Sopwith tractor biplane, made a long flight and a successful attack on the German Zeppelin Airship Shed at Dusseldorf.

"Lieutenant Collet's feat is notable—gliding down from 6,000 feet, the last 1,500 in mist, he finally came in sight of the Airship Shed at a height of 400 feet, only a quarter of a mile away from it.

"Flight Lieutenant Marix, acting under the orders of Squadron Commander Spenser Grey, carried out a successful attack on the Dusseldorf airship shed during the afternoon of the 8th October. From a height of 600 feet he dropped two bombs on the shed, and flames 500 feet high were seen within thirty seconds. The roof of the shed was also observed to collapse.

"Lieutenant Marix's machine was under heavy fire from rifles and mitrailleuse, and was five times hit whilst making the attack.

"Squadron Commander Spenser Grey, whilst in charge of a flight of naval aeroplanes at Antwerp, penetrated during a $3\frac{3}{4}$ hours' flight into the enemy country as far as Cologne on the 8th October. He circled the city under fire at 600 feet, and discharged his bombs on the military railway station. Considerable damage was done."

TWO MEMORIALS.

It is not difficult to realise how easily heroes of old became legendary abstractions when we reflect on our present attitude of mind towards the pioneers of flying. So rapid and remarkable has been the development of the science and the art that our historical perspective has suffered from that type of "foreshortening" which is so marked a characteristic of a photograph taken within a "wide angle" lens. Any attempt to view it from a distance leads to the background receding in a most disproportionate manner. So, when we try to review the aeronautical movement of only a few years ago, do we find that our minds have subconsciously pushed the "modern" pioneers much further back in point of time than we had realised. One hears Wilbur Wright referred to as if he were already archaic, although his active aeronautical career did not start till 1899, and ended only in 1912. How then is one to regard Pilcher, who commenced his aeronautical experiments in 1894, and who, in 1899, a little more than 15 years ago, was making those classic gliding experiments that were to lead to his death in September of that year? Fifteen years is a short time in the history of aeronautics, yet it has been long enough for us to advance from the sporadic attempts of early enthusiasts to the industry that already employs thousands of workers.

Pilcher, when he was killed, was only 34; he was a clever engineer and experimenter who was completing a screw-propelled power-driven machine and had all his best years in which to develop the flying machine that he all but achieved; who can say what would have been the history of flying had not a piece of thin piano wire been overstressed on that September day fifteen years ago? Would Pilcher have successfully overcome the stability difficulties that must have come to him as soon as he started extended power-driven flights? Who can say? Fame depends much on opportunity to deserve it. Pilcher has not the fame of the Wright Brothers, but he deserves our gratitude as one who ably kept alive the flame of hope that flickered so spasmodically all through the long years of waiting. The stone erected where he fell in 1899 will serve to show to future ages that we realised his worth.

Some of the pioneers of flight did not meet with violent ends, yet in one way their ends were very tragic, for they died without accomplishing what they had given so much to gain. Stringfellow, for example, only required a little more encouragement to have produced, fifty years or so ago, a man-carrying power-driven aeroplane. Those who have studied his work know how far he went towards that goal. Those who have not should read Aeronautical Classic No. 5 and study Stringfellow's models at the Science Museum and in the Society's possession. Here again, however, the stability question would soon have pulled him up short when he tried more than "hops." Would he have overcome it? Again, who can say? In any event, he made models that were much better aerodynamically than many made 50 years later by some pioneers who have groped their way to making successful flying machines. He had a very clear conception of the importance of flying at small angles and of reducing head resistance to a minimum. The man who, fifty years ago, went out of his way to fit a cork "fairing" of fish tail shape behind a round bamboo strut deserves our respect, and our sympathy that he was born in so unappreciative an age.

In his native village of Chard Stringfellow is secure of remembrance, thanks to the labours of Mr. James Gillingham, who, with much persistence and self-denial, has carried to a successful issue a memorial scheme, of which details

are given in the accompanying photographs. The Society donated £4 towards Mr. Gillingham's out-of-pocket expenses. Some day it is hoped to organise some permanent recognition in London of the early pioneers. Who, for example, would not wish the names of Cayley, Henson, Stringfellow, Pilcher, to be attached to Premiums awarded by the Society?

FIG. 5. JOHN STRINGFELLOW'S HOUSE AT CHARD. (The Medallion on house is shown separately in Fig. 6).

THE PILCHER MEMORIAL STONE, STANFORD PARK, NORTHAMPTONSHIRE. Erected by Lord Braye, with financial assistance (£25) from Members of the Aëronautical Society, in 1912.

(Situated half a mile north from Yelvertoft Station. The public road to South Kilworth runs through the field 200 yards from the spot, and the occupier of the land allows visitors to walk over the field to view the stone).

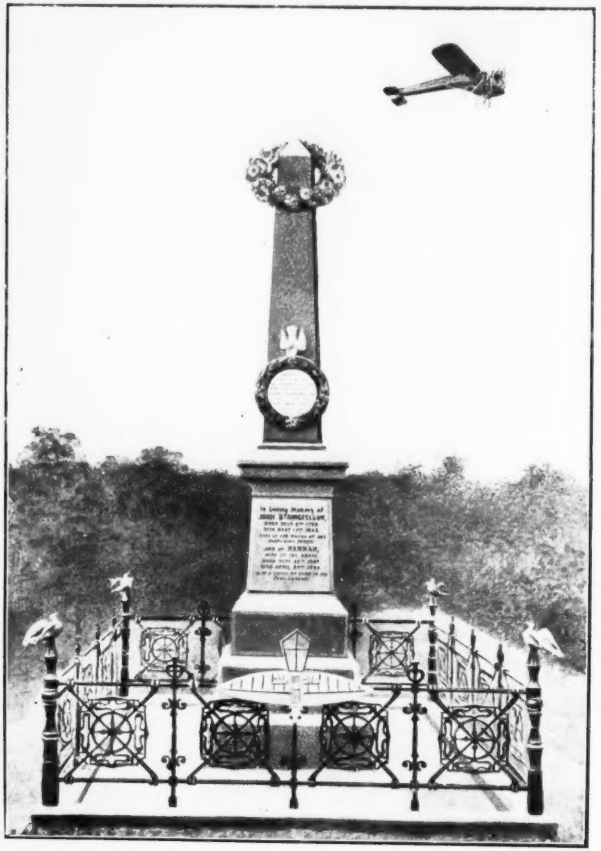

FIG. 1. THE STRINGFELLOW MEMORIAL IN CHARD CEMETERY.
(The Medallion is shown separately in Fig. 2).

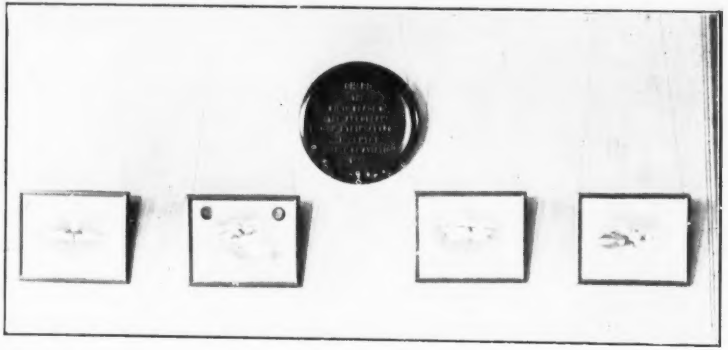

FIG. 3. MEDALLION (see also Fig. 4) AND PICTURES HUNG IN THE GUILDHALL, CHARD.

FIG. 2. MEDALLION IN CHARD CEMETERY.

FIG. 4. MEDALLION IN GUILDHALL, CHARD.

FIG. 6. MEDALLION ON STRINGFELLOW'S HOUSE. (See Fig. 5).

NEW BOOKS AND PUBLICATIONS.

*Nouvelles Récherches Sur la Résistance de l'Air et l'Aviation. G. Eiffel. Paris: H. Dunod et E. Pinat. 1914. Texte pp. 406. Figs., Atlas, pp. 67. Figs., 39 plates. Price 50 frs.

Flight Without Formulæ. Comm. Duchêne. Translated by John H. Ledeboer. London: Longmans, Green. 1914. pp. 211. Figs. Price 7s. 6d.

Simplification et Exactitude de la Technique de l'Aviation. Marchand Bey. Paris: J. Loubat et Cie. pp. 113. Figs.

Der Schwingenflug. G. Vorndran. Stuttgart: G. Vorndran. 1914. pp. 102. Figs. Price 3M.

*Anlage und Betrieb von Luftschiffhafen. Dip. Ing. Christians. Berlin: R. Oldenbourg. 1914. pp. 144. Figs. Price M.4.50.

*Die Angewandte Chemie in der Luftfahrt. Dr. G. Austerweil. Berlin: R. Oldenbourg. 1914. pp. 199. Figs. Price M.6.

Ninth Annual Report of the Meteorological Committee, 1914. London: H.M. Stationery Office. 1914. pp. 69. Price 4d.

*How to Understand Aeroplanes. S. L. Walkden. London: Published for the Author by Percival Marshall. 1914. pp. 99 + XVIII. Figs. Price 1s.

*Aircraft in War. J. M. Spaight, LL.D. London: Macmillan and Co., Ltd. 1914. pp. 172. Price 6s.

Motion of Liquids. Lieut.-Col. R. de Villamil, R.E. London: E. and F. N. Spon. 1914. pp. 205. Figs. and Tables. Price 7s. 6d.

*Sea, Land and Air Strategy. Sir George Aston. London: John Murray. 1914. pp. 308. Maps and Diagrams. Price 10s. 6d.

*The Art of Reconnaissance. Brig-Gen. D. Henderson. London: John Murray. pp. 197. (3rd Edition.) Price 5s.

All the World's Aircraft. Fred T. Jane. (0th year.) London: Sampson Low, Marston and Co. 1914. pp. 202. Illus. Price 21s.

The Aeroplane in War. Major W. S. Brancker. Extract from "The Army Review," Vol. VII., No. 1. London: H.M. Stationery Office. July, 1914. pp. 167-183.

The Essays of an Aviator. London: "Aeronautics." 1914. pp. 45. Price 2s. 6d.

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* See Review in present issue.

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REVIEWS.

Nouvelles Réchérches Sur la Résistance de l'Air et l'Aviation. G. Eiffel. (Paris: Dunod et Pinat. 1914. Texte pp. 406. Figs. Atlas pp. 67. Plates 39. Price 50 frs.)

Since the publication of "La Résistance de l'Air et l'Aviation," which contained work done in the Laboratory at the Champ de Mars, M. Eiffel has had to give up the latter laboratory and has built a new one at Auteuil. He has taken the opportunity of increasing both the size of his tunnel and the speed of the air current. (Strictly speaking it is more correct to call the installation a "Chambre Eiffel" instead of a "Tunnel Eiffel," owing to the tunnel being "broken" in the middle, as M. Eiffel points out.) The complete installation consists of a large helicoidal fan, in effect a screw propeller with many blades set round a drum, and a smaller "Sirocco" fan, each with its corresponding air tunnel. The large fan has given a speed of air current of 31.8 metres per second, using 61.5 horse-power, and the smaller fan an air speed of 40 metres a second with a motor of 60 horse-power. It will thus be seen that the speeds of air current are considerably higher than those that M. Eiffel and other investigators have previously had at their disposal. In view, however, of the types of fan used (the helicoidal fan has a very high pitch ratio), and the fact that no "dispersers" are fitted on the discharge side of the fan it is pretty clear that the fluctuations on the intake side, due to the circulation of the air in the shed, will be fairly considerable. From this point of view the wind tunnel evolved at the National Physical Laboratory is undoubtedly superior. M. Eiffel explains that he has retained the form of tunnel broken by a central chamber as being the most convenient and giving easy access to the models under test. The power used is electrical, 110 volts monophase, which is converted into continuous current for the purpose of being able easily to vary the speed. The voltage of the continuous current is variable from 0 to 265. The speed and regularity of the air current is measured by means of two pressure heads (combined pitot and static pressure tubes) connected to Schultze "inclined" alcohol micromanometers. One of these pressure heads is movable and can be placed before, behind, or around a model under test, the other is placed in the air current at the entrance to the experimental chamber.

The principal aerodynamical balance is the same as that used in the old laboratory with certain improvements. Owing, however, to the difficulty of measuring with this balance very small horizontal forces a simple balance arm with scale pan attached, projecting downwards, has been installed for use when desired.

Owing to the speed of the new air current the pressures on the models are such that they and their supports flex from the position they occupy when out of the air current. A telescope has therefore been installed, the eye-piece of which is square ruled, enabling the exact angle of incidence of a model to be investigated when under test.

For driving air-screws under test in the air current the motor is mounted above the experimental chamber and drives the air-screw by means of a vertical shaft and bevel gear. The whole of the motor and air-screw mounting is free to rock on a universal joint, and by means of two manometers the torque and thrust can be measured. A mercury manometer is used for the thrust and a water manometer for torque.

An improvement has been introduced in the polar diagrams by representing the components K_x and K_y on different scales with the object of rendering easier comparison between one wing and another by superposition of their diagrams.

For the purpose of studying the characteristics of complete machines, either models or full size, instead of simply those of wings, the ordinary polar curves are replaced by others obtained by using the logarithms of the lift and drag forces.

In this connection the transition between models of various sizes has been cleverly accomplished. The effect of altered centre of gravity and position of elevator has also been dealt with, as also has the effect of altitude upon the motor, and of flying on an inclined path. It cannot be said, however, that the treatment of stability is at all complete, in fact M. Eiffel is of opinion that "Le problème de la stabilité d'un aeroplane est trop complexe pour être résolu théoriquement. . . . La pratique peut seule, par un perfectionnement graduel des réflexes des pilotes, résoudre un probleme qui présente à la théorie des obstacles aussi insurmontables." This is rule-of-thumb with a vengeance! We, who know what has been done by the National Physical Laboratory and the R.A.F., following the masterly analysis of Bryan, cannot help regretting that the great resources of M. Eiffel's laboratory should have been so appalled at the problem of stability in disturbed air that they confined themselves to the simple ascertainment of restoring couples round a transverse axis with the machine at various angles of incidence in calm air. The damping out of oscillations by favourable couples is mentioned, but periodic oscillations are not considered.

Chapter III. deals with the resistance of spheres, hemispherical cups, cylinders end- and broadside-on, wires and cables, struts, and streamline bodies. The influence of speed of air flow upon the character of the results obtained in wind channels is now receiving the attention its importance demands. Many results published hitherto, and accepted as standard, are completely falsified unless it is borne in mind how very important is the relation between the velocity of the current and the dimensions of the model. M. Eiffel examines the case in regard to certain experiments on spheres. It cannot be said that the results obtained quite clear up the matter, and M. Eiffel finds that his figures do not bear out the contention that the product of the critical velocity by the diameter of the spheres is practically constant. In endeavouring to find the reason for the anomaly M. Eiffel has explored, by means of a light thread, the air currents round the sphere, showing that there are two régimes of flow, and has also taken readings of the pressure distribution round the sphere. He has obtained a "butterfly" diagram similar to those shown by Dr. Thurston in his paper (pages 140-155, AËRONAUTICAL JOURNAL, July, 1913), for speeds inferior to the critical velocity. For speeds over this velocity the "butterfly" diagram alters very considerably in character, its "aspect ratio" being increased over 50%. For cylinders broadside-on much the same results as for the spheres were obtained. M. Eiffel's experiments on wires lead him to the same results as those of Dr. Stanton (which, according to M. Eiffel, were obtained in the laboratory of the East London College). The results on cables agree with those of Dr. Prandtl, of Göttingen.

Three Maurice Farman struts were tested with the axis both at right angles to the wind and inclined. M. Eiffel finds that the coefficient K_x varies with the speed. Certain streamline bodies were tested at the request of M. Pateras Pescara without showing anything striking. In fact, the N.P.L. results both on bodies and struts are much ahead of those given here.

Chapter IV. is devoted to tests of wings. These, while of interest, are rather disconnected, as is indeed much of the research conducted by M. Eiffel, owing to the fact that he tests gratuitously "anything that comes along" as it were. In the case of some wings a variation of resistance occurred with speed, but this is not fully elucidated. We find here the Constantin wing and the Howard Wright amongst the most interesting. It is to be hoped that much more complete experiments will be made with regard to the provision of a "beak"

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on the front of the cross section of a wing. Meantime M. Eiffel's experiments show it to be beneficial.

Chapter V. is devoted to the interference of wings either in tandem or superposed, and some very interesting results are given, which are generally too long to be detailed here. One of the most important is that "staggering" biplanes improves their efficiency.

Complete models of aeroplanes are dealt with in Chapter VI. Seventeen different machines were tested at the request of their respective constructors. Some of the models are, it is to be feared, of not much practical importance.

The results obtained by MM. Toussaint et Lepère on a full size Maurice Farman biplane are compared with M. Eiffel's results on a model, with very fair agreement.

A very useful table is given comparing the characteristics of the various models tested.

Chapter VII. gives results of tests on landing wheels, floats, and streamline aeroplane bodies. The covering in of spokes of wheels is shown to be of considerable advantage. Two very nice models of Deperdussin "monocoque" bodies were tested, for the Gordon-Bennett model 1912, and showed that the screw and motor in front, when revolving, added to the resistance. M. Eiffel explains this on the ground that the revolving body acted as a brake on the airscrew, a component of the force of which acted along the line of flight. Why the effect of the revolving screw and motor on the streamline system round the body should be ignored is not quite clear. It is shown that the Farman body gives more resistance than that of the Deperdussin.

Chapter VIII. is concerned with dirigible shapes. Distribution of pressure has been explored, with the axis parallel and inclined to the flight path. The difficulty of proceeding from small models to full size airships, owing to the great disparity in size and the distortion of the full size envelope, is discussed.

The wind pressure on airship sheds is treated in Chapter IX., and is a most important line of research, leading, it is to be hoped, to some full experiments of the effect on air currents of the shape of the ground over which they are blowing.

Airscrews are considered at some length in Chapter X. Some very interesting data are given on the air speed in front and behind the airscrew, the effect of thickness and pitch on deformation, and effect of number of blades. M. Eiffel does not himself attempt to apply the method of Drzewiecki to his experimental results, but in a supplementary note (No. VI.) gives a short discussion of the theory, with the conclusion that "test results approach sufficiently near to calculated values to make the method employed legitimate." The fact that the inflow has a certain velocity, making the speed of the air current on the blade slightly different from the speed of translation, is of slight importance in practice.

Seven "Notes Complémentaires" are appended, the first dealing with a comparison of the full size experiments at St. Cyr with those in the laboratory at Auteuil, the second with the "Qualité Motrice" of M. L. Breguet, the third with Fuhrmann's experiments at Göttingen on dirigibles, the fourth with the fundamental formulæ of airscrews, the fifth with groups of airscrews of variable dimensions, the sixth with Drzewiecki's theory of airscrews, and the seventh, an answer to various objections. This latter is most interesting.

An explanatory note, on drawing airscrew diagrams, follows, and the volume is finished by the publication of the conditions under which M. Eiffel undertakes

tests on models. The most important statement is "these tests are free." The gratuitous testing of models of machines as they are sent along is an important and valuable work, for which inventors can never be too grateful to M. Eiffel. It inevitably, however, leads to a large amount of somewhat disconnected, and from the purely scientific point of view relatively unimportant, work being done. But one must not look a gift horse in the mouth.

The Art of Reconnaissance. Brig.-Gen. Sir David Henderson. (London: John Murray. 1914. pp. 197. (3rd edition.) Price 5s.)

In the preface to the third edition, the author writes:—"In the seven years which have elapsed since this book was first published, the power of flight has been added to the resources of mankind. Whatever may be the influence of the art of flying on the future developments of civilisation, this influence is, as yet, apparent only in one direction, that of warfare, and in its application to warfare the new art has already affected reconnaissance. A book on reconnaissance in which the possibilities of aerial scouting are not considered must be classed as obsolete; and yet, in this new field, experience is so limited, and progress is so rapid, that any dogmatic pronouncement on military aeronautics would, at this stage, have no permanence and little value. I have, therefore, in this new edition done no more than add a chapter on aerial reconnaissance, in which will be found some indication of the results which have already been produced by the introduction of a third dimension into the problem of war."

No one is better fitted to write such a chapter than Brigadier-General Sir David Henderson, who was the first officer of his rank to qualify as a pilot, and who, after conducting the War Office trials for military aeroplanes, two years ago, was appointed Director of Military Aeronautics, in which capacity he is now serving in the great war.

The purpose of this review is primarily to deal with the chapter on aerial reconnaissance, but before dealing with this chapter specifically, it may be permitted to emphasise the very high military value of the book as a whole, and to draw particular attention to the inculcation of certain principles which affect all kinds of reconnaissance, aerial or otherwise.

Thus, in the chapter on "The reconnaissance of ground" we find—"When the enemy and the ground must be examined simultaneously, and their influence on each other considered, the highest skill in reconnaissance is required, for this mutual influence is often of extreme importance. The study of ground in its military aspect may be conveniently divided into the appreciation of its possibilities and the ability to reproduce its features. Knowledge of the possible influence of ground is one of the first essentials of military training." The author proceeds to point out the necessity for a scout or observer to be able to look at the situation from the point of view of a commander, if his information is to be of any value. "There are some who scoff," he writes, "at the idea of subalterns being taught to 'think in Army Corps,' but there may be, as there have been, occasions when momentous decisions have to be made on no better information than is contained in a subaltern's report." How particularly applicable this remark is to the case of the air scout, needs not to be insisted on.

In regard to sketches, the author remarks:—"The value of freehand sketches, as of rough maps, is entirely dependent on the military value of the ground depicted. . . . If a position held by the enemy is being reconnoitred, a rough sketch from eye or memory, showing the approaches to the position, may be of great assistance to the commander, because of the extreme importance of informa-

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tion concerning this particular piece of ground." Again—" The relevance, which in reconnaissance is almost the same as the military value of a report, is a matter which cannot always be within the scout's knowledge, . . . therefore every officer should consider how much of a report is of value to himself alone, and how much is worth transmitting to his superior."

Brigadier-General Henderson correctly foresaw that " At the outset of a civilised war, the information obtainable by aircraft will undoubtedly be open to both sides. Possibly, by continual interference and by the display of superior resolution, the enemy's courage may be worn down, and something like the mastery of the air secured." The correctness of this forecast is borne out by Sir John French's despatch, dated September 11th, in which he says:—" The constant object of our aviators has been to effect the accurate location of the enemy's forces, and incidentally—since the operations cover so large an area—of our own units. Nevertheless, the tactics adopted for dealing with hostile aircraft are to attack them instantly with one or more British machines. This has been so far successful that in five cases German pilots or observers have been shot in the air and their machines brought to the ground. As a consequence, the British Flying Corps has succeeded in establishing an individual ascendancy, which is as serviceable to us as it is damaging to the enemy. . . . Something in the direction of the mastery of the air has already been gained."

The author's remarks on the influence of aerial reconnaissance on the accepted system of employing independent cavalry are noteworthy. He says, " Four duties have been allotted to the independent cavalry:—(1) To find the enemy's cavalry. (2) To beat it. (3) To find the enemy's main bodies. (4) To keep touch with them. It seems probable that, in future, the first and third of these duties will be carried out by aircraft."

The author has also made a correct forecast in his statement that " aircraft will probably be of much assistance to artillery in indicating concealed targets." How true this is we know by sad experience; it is permissible to rejoice that the Germans have experienced similar treatment at our hands.

The conclusion of this chapter should be taken to heart by all keen soldiers:—" Flying, either as a pilot or as a passenger, has become in fact an essential part of the education of an officer who aspires to advancement in his profession."

F. G. STONE.

Sea, Land, and Air Strategy. Sir George Aston, K.C.B. (London: John Murray. 1914. pp. 308. Maps and diagrams. Price 10s. 6d.)

Sir George Aston is well known to the officers of the Navy and Army as the author of " Letters on Amphibious Wars," and his lectures at the Staff College, at Camberley, from 1904-7, have made the author, as well as his subject, familiar to a very large number of staff officers. The present volume brings together in clearly arranged sequence the valuable matter which is scattered through the " Letters," and which formed the thesis of the Staff College lectures, together with an admirable chapter on Air Warfare, which is entirely new. The book is eminently readable, and may be taken up without misgiving by the intelligent but non-military or naval reader; there is not a page which is too dry or too technical to be of general interest, and the addition of an excellent index makes it a really useful work of reference.

At a time like the present, when so many people are following with intense interest the progress of the greatest war which the world has ever seen, and are studying the psychology of a situation pregnant with the most stupendous issues to the present and future of nations, this volume will be welcomed as a guide in

the difficult mazes of the art of strategy, which will help the non-professional reader to a juster appreciation of the significance of the successive acts of the great drama which is now being played on the world's stage, than would be possible without some such expert guidance.

In the chapter on air warfare, the author follows the same course in the investigation of principles and broad issues, as he has adopted in dealing with land and sea warfare, thus:—"Our object in this chapter will be to investigate from the same point of view whether recent developments in the art of flying compel us to study strategy in three dimensions, because the armed forces are no longer confined to the surface of the earth. In undertaking this investigation, it is important to go back to our original standpoint, and to discuss the results which the population of one country can produce upon the population of another country by resorting to air warfare. By so doing we shall avoid any conception of war as a sort of gladiatorial combat in which the nations concerned have no direct personal interest beyond providing the picked combatants and equipping them with weapons and resources for movement. . . . A proud nation profoundly stirred by the justice of its cause, does not give in to an opponent unless the population can be made to feel the threat of starvation or some equally effective pressure."

Having thus ensured that the ultimate issue shall be kept clearly in view, the author proceeds to discuss in some detail the bearing of aircraft on that issue in (1) sea warfare, (2) in land warfare, and (3) in amphibious warfare, and "to cover the case of the combats likely to occur between the aircraft themselves in carrying out their mission" he considers (4) combats between aircraft.

This chapter can be read with the greatest profit by all students of aeronautics, for, while the reader is, in a sense, ahead of the writer in some of the actual experiences of the present war, this fact does not in any way discount the value of it, in helping the student to co-ordinate his ideas and experiences in proper relation to each other and to the great issues at stake, to maintain a sense of proportion and perspective, and to focus his attention on essentials instead of allowing it to be too much arrested by picturesque but unessential details.

F. G. STONE.

Aircraft in War. J. M. Spaight, LL.D. (London: Macmillan and Co. 1914. pp. 172. Price 6s.)

This is a fairly exhaustive treatise on the attitude of International Law towards the question of aircraft in war. The subject is one full of complication, and in the light of current events in Europe and elsewhere, seems to have become more complicated by the action of the belligerents. The idea so strongly held by some, and opposed with equal strength by others, in this country, that belligerents would be bound by the Hague Convention in respect to their method of aerial warfare, has at any rate been completely disposed of so far as one of the belligerents is concerned; we know definitely that Germany recognises no law either in the air or anywhere else, and the difficulty faces every civilised nation in the future as to how they are to legislate by international agreement in respect to the laws and customs of war, when it is notorious that one of the parties to the agreement will cynically disavow her bond whenever it suits her. The answer to this question however seems obviously to rest outside the law, just as the nation in question must, by its own choice, remain outside the comity of civilised nations; such a nation can only be prevented by forcible methods from transgressing the law, and it rests with the civilised Powers of the world to restrain her in the future from breaking the law; in the meantime, it seems more impor-

tant than ever to formulate our ideas with precision on all the knotty points which have arisen or may arise, and to obtain such agreement among civilised Powers as may lead to clear, and we may hope concise, codification.

No doubt the chapters which will be read with the greatest and most general interest are those which deal with the bombardment of *undefended* cities; this subject simply bristles with difficulties, and the tendency is for these difficulties to be increased by recent procedure. It is impossible in a review of this nature to deal effectively with the subject, we can only say that the author has enabled us to study it from every point of view, and to realise how serious the difficulties are, even when with the best will in the world civilised Powers are honestly trying to come to a suitable agreement.

The author devotes a good deal of consideration to the subject of neutral aircraft and gives a most valuable table, showing how they should be dealt with under various circumstances.

There is an excellent index and the subject matter of the book is admirably arranged both for study and for reference; it is a valuable addition to the library and should be read by all who wish to obtain an insight into a subject which, however remote it may appear to be in the abstract from the interest of the general public, is liable at any moment to become of absorbing interest in very concrete form to every man, woman and child in our streets.

F. G. STONE.

Technical Report of the Advisory Committee for Aeronautics for 1912-13 (with Appendices). (London: Wyman and Sons. 1914. 416 pp. Illus. Plates and Diagrams. Price 10s.)

This is perhaps the most interesting of the reports published by the Advisory Committee, as it contains a great deal of information useful to designers of aeroplanes. As the individual reports of work done are not arranged in any particular order, the most convenient way of describing them will be to take them in groups, each group being composed of those relating to some particular subject. and this is done in the account given below.

GROUP I.—WIND TUNNELS, ETC. REPORTS NO. 67, 68, 75, 78.

Report No. 67.—*Steadiness of Wind Channels, etc., and the effect of the buildings in which they are enclosed.*—This is a particularly interesting report, as there is a full description of the new 4ft. tunnel, and an explanation of the reasons why the type used for the 2ft. channel, described in previous reports, was abandoned. Briefly, it was found that in a larger tunnel of the return stream class it was impossible to free the air from pulsations of considerable magnitude, and consequently some other system had to be devised. In the new type tunnel the air is drawn in through a bell-mouth as before, but instead of returning it through a special channel outside the tunnel it is passed into a kind of large box in rear, fitted with slots in the sides, which break up the currents in such a way that when the air leaves the box it is practically at rest. Provided then that the air in the room enclosing the tunnel is not obstructed by projections, etc., the bell-mouth receives undisturbed air, and hence a good steady flow, free from pulsations, etc., is obtained.

The report contains a full description of the numerous experiments tried, and points out the importance of having the enclosing room of a suitable size and perfectly free from obstructions, such as large wall projections, etc.

This system with the perforated box seems to work satisfactorily. For good results the enclosing room should be at least 6 by 6 by 15 channel diameters.

Report No. 68.—*The New 4ft. Wind Channel.*—This contains a good general description of the new channel, and the plans accompanying it give the necessary details. The balance, which is of a new type, has three arms mutually at right angles to each other, each arm being counter-balanced. The centre lines of these arms meet in a point at which a steel centre is fixed. The weight of the balance is taken on this point, which rests in a hollow cone, in a column from the floor of the room. The vertical arm of the balance passes through the underside of the tunnel and supports the model under test. This is not very clearly shown in the plans, etc., but the position of the base of the balance is directly under the trap-door, shown in the elevation of the tunnel, and the rod for holding the object to be tested passes up through the bottom of the channel. The advantage of this type of balance is that it simplifies taking the readings and allows of several of them being obtained with one setting of the instrument.

There is a very interesting diagram, Fig. 5, giving the distribution of the pressure across the section of the tunnel where the model is placed; these pressures are remarkably regular over a central space of 2½ft. by 2½ft., and provided the maximum dimension of the model does not exceed 2ft., very accurate results should be obtained.

There is a fairly full description of the method of using the balance, but the reader will do well to visit the laboratory and inspect the actual working of the instrument, as the plans are not (quite properly) very detailed.

Report No. 75.—*Method of Experimental Determination of the Forces, etc.*—In this a fairly detailed explanation of the method employed in measuring the forces, moments, etc., is given. The subject is a complicated one, and will be best understood by seeing the apparatus in use. Fig. 1 shows the moment measuring apparatus, an important adjunct which (taking the moments round an axis four inches below the centre of the model) allows considerable accuracy of measurement. In an appendix the results obtained with a Bleriot type monoplane model are given as an example of the method of using the instrument.

Report No. 78.—*The Experimental Determination of the Rotary Co-efficients.*—This contains an account of the apparatus and method employed for measuring the value of these co-efficients; five different (principal) kinds of moments being considered. The apparatus is complicated and will be best understood by seeing it in use.

As regards the importance of these rotary co-efficients, Mr. Bairstow states (see AËRONAUTICAL JOURNAL, April, 1914, p. 84) that he agrees with me, that as far as longitudinal stability is concerned they can, generally speaking, be ignored. On the other hand, he states that as regards lateral stability they are very important and must be taken into consideration.

GROUP II.—STABILITY, ETC. No. 77, 79.

Report No. 77.—*Investigation into the Stability of an Aeroplane, etc.*—This report commences with a consideration of what is meant by "stability," and it is explained that while the account given of the procedure employed applies to the mathematical theory of stability, it would seem to be quite possible to apply it to all ordinary disturbances which commonly occur in practice, though, of course, cases such as the "vol piqué" require special treatment.

The actual method of investigation is based upon Professor Bryan's theory, as described in his book on "Stability in Aviation," commencing, however, with the most general case of the subject. A somewhat different system of axes is used, as these new ones have the advantage of giving positive signs to the fundamental quantities such as lift, drag, etc., when taken with their ordinary meaning, but otherwise the usual procedure is followed. Finally, simplifications for practical use are discussed and it is shown that a very good idea of the

stability of a given machine can be obtained, once the necessary measurements, lift, drag, moments, etc., have been found. This is, of course, of very great importance as it will materially assist in solving the most difficult of all the problems connected with aerial flight.

Report No. 79.—*Longitudinal and Lateral Stability of a Monoplane of the Bleriot Type.*—This report will be found of special interest by designers of aeroplanes, as it describes the practical application of the foregoing theories to an actual machine. A model of this machine was tested (see Report No. 75) and from the data obtained the conditions for a full-sized machine are worked out and applied to calculating the details required for both longitudinal and lateral stability.

GROUP III.—MODEL TESTS (AEROPLANES). REPORTS NOS. 72, 73, 74.

Report No. 72.—*Experiments on Models of Aeroplane Wings.*—These were divided into nine different classes. In Class I. it was found that varying the position of the maximum ordinate had, as was to be expected, a marked influence on the lift and drag curve after the critical angle had been passed. For the particular type of model tested the best position for the maximum ordinate appeared to be at about three-eighths the length of the chord from the front edge. In Class II. it was found that there was no particular advantage in thickening the front edge of the types experimented with. Class III. included four different kinds of aerofoils; the chief result found was that the Phillips entry was not particularly advantageous. The result of Class IV. experiments, viz., thickening the rear edge of an aerofoil, showed that provided this was not carried to extremes no particular harm was done. In Class V. the air speeds were varied between 10ft. and 50ft. per sec.; the results are important as there was considerable variation in the force co-efficient with the changes of speed. Class VIII. experiments show the effects of warping; and Class IX. the result of reverse curvature of the trailing edge. This last type was suggested by me in the paper I wrote for the International Conference on Aerial Navigation, Chicago, 1893, p. 244, and confirms what I pointed out, that with such an aerofoil the centre of pressure can be made practically stationary if it is well designed.

Report No. 73.—*Investigation of the Distribution of Pressure Over an Aerofoil.*—This experiment is a very important one as it shows the distribution of the pressures all over a certain type of aerofoil 18in. by 3in. It would be a great advantage if further tests were made on aerofoils with better shaped ends, as the shape of the tips has a very considerable influence on the type of air flow and consequently on the stability of the system.

Report No. 74.—Gives an account of experiments on models of struts, certain types of aeroplane bodies, elevating planes, etc., and will be found interesting. It should be particularly noticed that a very great reduction in the resistance can be made by designing the body of a machine in a suitable manner. On the other hand, however, it must be recollected that there appears to be a definite connection between the resistance of the aerofoil and the resistance of a body suited to it and that consequently care must be taken to make the two designs harmonise.

GROUP IV.—PROPELLERS. REPORT NO. 82.

Report No. 82.—*Experiments on Model Propellers.*—The object of these experiments was to find the changes in efficiency and thrust of a propeller, due to change of form of the blade section (plan form and pitch remaining constant), and also the effect of varying the angle of the blades. Two Ratmanoff propellers were tested and full details of the results obtained are given. The under faces of these propellers differed considerably, E type being more hollowed out than

D, but there did not seem to have been much difference in their maximum efficiency. No doubt the upper face is the most important factor in blades of the sections given, but it does not follow that this will be the case with all sections. As regards the latter part of the experiments, viz., varying the angle of attack of the blades, the system is practically the same as the one suggested by me in the "Royal Engineer Journal," December 1st, 1897. The calculated results appear on the whole to agree with the experimental results very fairly well.

GROUP V.—STRESS CALCULATIONS. REPORTS NO. 83, 84, 85.

Report No. 83.—*Determination of the Stresses in Aeroplane Wings.*—In this an approximate method of finding the stresses in the spars forming the main supports of a wing is given. It should be particularly noticed that the forces calculated are the vertical ones only; other forces, due to drag, are not considered, while additional stresses, such as those caused by the bracing, must be separately calculated and arithmetically added as required. A complete account of a good approximate method is given, and the bending moments calculated by the theorem of three moments in the usual way. A numerical example is worked out and the application to a biplane wing is discussed. Particular attention is drawn to the distortion sometimes caused by the stretching of the wires used, as this is of considerable importance.

Report No. 84.—*Stresses in the Fabric, etc.*—A brief account of this subject is given, as also of the effect on the attachments of the fabric to the ribs.

Report No. 85.—*Note on Wing Covering.*—This contains an account of the method recommended for attaching the fabric to aeroplane ribs, the general idea being shown by an explanatory diagram.

GROUP VI.—MODEL TESTS (HYDRO-AEROPLANES). REPORTS NO. 69 AND 70.

Report No. 69.—*Floats for Hydro-Aeroplanes.*—This is an account of some experiments carried out by Commander Schwann, R.N., and is dated December, 1911. Different kinds of floats were fitted to an Avro machine and the results are summarised.

Report No. 70.—*Experiments on the Design of Floats for Hydro-Aeroplanes.*—This report gives a description of the apparatus used for the tests at the "William Froude" National Tank and a full account of the experiments made with various kinds of floats. In the appendix is an account of a test made in air, in a wind tunnel. There is a good deal of interesting information in this report, but much further experimental work will be necessary before the best shape for these floats can be found.

GROUP VII.—MATERIALS AND FABRICS, ETC. REPORTS NO. 87, 88, 89, 90 AND 91.

Report No. 87.—*Leakage of Air and Hydrogen through Balloon Fabrics.*

Report No. 88.—*Rapid Method of Determining the Lifting Power of Samples of Hydrogen.*

Report No. 89.—*Gelatine as a Proofing for Balloon Fabrics.*

Report No. 90.—*Experiments on Aeroplane Fabrics.*—This includes, among other questions, weathering tests of fabrics; tests of a fabric after use on an aeroplane; tests of doped fabrics, etc.

Report No. 91.—*Light Alloys.*—This is a general summary of the light alloy question up to September, 1913. It contains a great deal of valuable information as to the strength of these alloys and some useful notes on their permanence, elastic properties, corrosion under certain circumstances, etc. An appendix gives detailed results of tests on duralumin.

GROUP VIII.—FULL SCALE TESTS AT THE ROYAL AIRCRAFT FACTORY. REPORT NO. 86.

Report No. 86.—*Full Scale Tests, etc.*—This describes a good deal of the work done at the factory up to March, 1913. The work is divided into six parts, but only four of these are discussed in detail.

General Improvement of the Aeroplane.—In this a great many points are examined, such as speed, accuracy of control, self-righting, stability, safe alighting, etc., etc. There is an interesting comparison between the calculated and observed resistances of BE2; these calculations are somewhat approximate as there were not at the time sufficient reliable data to go upon, but more favourable results will no doubt be obtained in future. There is a good stability chart with a full discussion of the results obtained (see p. 255). The question of gusts and how they affect a machine is considered, and there are some interesting remarks on landing gear, loading tests, etc.

In the latter part of the report different types of aeroplanes are discussed under the headings of "High Speed Scouts," "Reconnaissance Aeroplanes," and "Gun-Carrying Aeroplanes," with some notes on "Sea Planes."

As regards the "High Speed Scouts," B.S. 1 did on test from 51 miles to 91.7 miles per hour with a climbing rate of 900ft. per minute when loaded with fuel and oil for three hours, a good performance. R.E. 1, a reconnaissance aeroplane, varied its speed from 43 to 78 m.p.h. and climbed at the rate of 600ft. per minute, but it had a 70 h.p. motor instead of 100 h.p. as in the former case. F.E. 3 was designed for gun-carrying, and had a maximum speed of 75 m.p.h.; no details as to the gun are given.

There are good diagrams accompanying this report.

GROUP IX.—METEOROLOGY. REPORTS NO. 92 AND 93.

Report No. 92.—*Fourth Report on Wind Structure.*—This is a very elaborate and excellently illustrated paper containing accounts of the diurnal variation of wind velocity at S. Farnborough during October and November, 1912; description of a combined velocity—direction anemograph; a note on cliff eddies, and a comparison between the gradient and surface winds at Pyrton Hill and Southport. The very elaborate wind and weather diagrams are extremely interesting, as is also the wind current behind the stables diagram, Fig. 4. The latter shows clearly a well-defined surface of separation in rear of the buildings, very similar to the pool in rear of a plane surface described in the Helmholtz—Kirchoff theory of fluid motion.

GROUP X.—MISCELLANEOUS PAPERS. NOS. 71, 76, 81 AND 94.

Report No. 71.—*Determination of the Pressure-Velocity Constant for a Pitot Tube on the Whirling Arm, etc.*

Report No. 76.—*Photographic Investigation of the Flow Round a Model Aerofoil.*—This is an interesting paper, accompanied by two sets of photographs, the first showing the flow behind an aerofoil at various angles of incidence to the stream; the second giving cinematograph pictures of the growth of eddies behind a cylinder and an aerofoil. The latter set are particularly good.

Report No. 81.—*Note Relative to Gyroscopic Couples in Aeroplanes.*—The result of the experiments appears to be that these couples are not of any great importance.

Report No. 94.—*Surface Cooling and Skin Friction.*—In this an attempt is made to connect skin friction with the capacity a surface has for absorbing heat from or emitting it to a fluid. Various calculations are made and the case of a

50 h.p. motor with a 16ft. cooling surface is gone into, but in the present state of our knowledge of skin friction such calculations are of doubtful value. The report concludes with an appendix on this subject by Dr. Stanton.

Taken as a whole, this Report of the Advisory Committee for 1912-13 is a very interesting one, and it will be found useful by constructors and those interested in designing machines. The summary of the work on page 7 will be found helpful.

J. D. FULLERTON,
Colonel, R.E. (ret.).

Leitfaden der drahtlosen Telegraphie fur die Luftfahrt. Dr. Max Dieckmann. Munchen und Berlin, 1913 : R. Oldenbourg. pp. X + 214. Illus. Price 8M.

Die Wasserdrachen. J. Hofmann. Munchen und Berlin, 1913 : R. Oldenbourg. pp. 83. Figs. Price 4M.

Die angewandte Chemie in der Luftfahrt. Dr. G. Austerweil. Munchen und Berlin : R. Oldenbourg. 1914. pp. 199. Figs. Price 6M.

Warnende Stimmen in Bezug auf Zeppelin-Ballons. Victor Silberer. Wien : L. W. Seidel & Sohn. 1914. pp. 34.

Grundlagen der Physik des Fluges. Dr. R. Nimführ. Wien : R. v. Waldheim, Jos. Eberle & Co. 1913. pp. 106. Figs.

Beitrag zur Berechnung der Luftschrauben. Dipl. Ing. C. Dornier. Berlin : J. Springer. 1912. pp. 108. Figs.

Die Gesetze des Wasser und Luftwiderstandes. Dr. O. Martienssen. Berlin : J. Springer. 1913. pp. 130. Figs.

Das Naturgesetz des freien Schwebens der Vögel. F. H. C. Mordhorst. Kiel und Leipzig : Lipsius & Tischer. 1913. pp. 15. Price M.0.60.

In reviewing a batch of German publications on the technology of flying, it is pertinent to preface that the present reviewer had occasion to remark in opening the discussion on Mr. C. T. Weymann's paper* that while the French in the past had possessed the soundest body of doctrine in aeroplane theory it was the Germans who already at that date had the largest number of experimenters and technicians examining the bases of Mechanical Flight. The prediction was ventured on that in the not distant future the Germans would be our most formidable competitors in the struggle for air supremacy.

Shortly after, as chance had it, these same Germans began to pick up all the duration records. It became the fashion immediately to acclaim the German machines as the most advanced product of Aeronautical Science. This view was as premature as the former neglect of German progress was reprehensible.

But to return to the subject matter of the review. There is no doubt that in due time the reward of systematic technical studies till recently being made and published, will follow as surely as the day the night.

Nos. 13, 14 and 16 of the series of Handbooks edited by George Paul Neumann, under the title of "Luftfahrzeugbau und Führung," vary somewhat in the extent of knowledge presupposed. No. 13, *Leitfaden der drahtlosen Telegraphie für die Luftfahrt*, by Dr. Max Dieckmann, is an introduction to the simplest elements of wireless telegraphy, suitable for engineers who have some acquaintance with the meaning and significance of electric current, voltage, resistance, reactance, and capacity, and who know what a differential equation means.

The differential equation of damped electro magnetic oscillations is obtained in a simple manner, and the solutions are illustrated by numerical and graphical examples.

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* See AËRONAUTICAL JOURNAL, January, 1914, page 49.

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On this groundwork an excellent elementary description of the apparatus of wireless telegraphy is based, both the mechanical appearance and the electromagnetic functions of each item of the operating room being made familiar to the reader. The graphical representation of the wave surfaces is illuminating.

The simpler applications are well described. The student who has digested this book should be in a position to profit immediately and intelligently by practical instruction.

A receiver which will take messages up to 400 kilometers may weigh as little as one kilogram. (Dr. E. F. Huth's receiver, Fig. 137, pp. 183-184). To despatch messages a larger apparatus is required.

On page 187 is described Ferrié's despatcher, Fig. 139, size 50 × 60 × 55 cm. Range in connection with a portable military receiving station, 200 km. The weight given is 120kg. for the complete installation with station, rather excessive for an aeroplane.

A lighter machine with battery with a range to a military portable station of 25 km. weighs only 25 kg., which is easily within the spare carrying power of an aeroplane. The method of obtaining position from the intensity of signals sent in particular directions from a central station specially equipped is illustrated on page 201, but as this necessitates receiving messages it is only practicable for airships.

No. 14, *Die Wasserdrachen* (Seaplanes), by Joseph Hofmann, opens with an analysis of the combined air and water resistance, and gives a method of calculating the best compromise between the two for the shortest run before leaving the water.

The form of the analysis is excellent, but the empirical equations for lift and drag certainly need revision. The chapters on rolling, pitching, wave action, are much elaborated, without giving a great deal of useful information to the designer.

The descriptive chapters, V. and VI., on combined wheels and floats, and on the construction of floats, have a large number of excellently produced sketches and drawings.

In Chapter VII. the principal conditions for the Monaco Competition of April, 1913, are tabulated.

No. 16, *Die angewandte Chemie in der Luftfahrt* (Chemistry applied to Aeronautics), by Dr. G. Austerweil, is a somewhat discursive book on the mechanical, physical and chemical properties of the materials of construction.

The suggestion on page 8 that non-inflammable helium might replace hydogen is no doubt the basis of a current rumour that German Zeppelins are, at the present stage of the war, being filled with a secret non-inflammable gas.

Chapters II.-IX. are chiefly devoted to permeability tests of various materials.

The chapters (XII. and XIV.) on varnishes (colloquially known as "dopes") are of interest to constructors.

The book as a whole is somewhat of a miscellany.

Warnende Stimmen in Bezug auf Zeppelin-Ballons. A collection of highly rhapsodical German and Austrian protests against spending more money and lives on Zeppelins.

The following example will suffice :—

"Die Standarte," Berlin, October 21, 1913.

"THE COLLAPSE OF THE ZEPPELIN SYSTEM.—. . . A dreadful, bloody event! The tenth airship of Count Zeppelin is annihilated. And this Count

can still laugh—can still support the further building of his vessels! . . . Thirty manly lives in their bloom have found a premature grave in L2. . . . But we shall see; new Zeppelins will be built, new catastrophies are inevitable with this doomed system, . . ." and so on.

Grundlagen der Physik des Fluges, Dr. R. Nimfuhr, is chiefly an account of meteorological variations in the earth's atmosphere.

The effect of variable density is discussed at great length by means of empirical equations of flight.

The discussion is very lengthy, but the conclusions seem remote from the problems urgently requiring solution from the designer's point of view.

Beitrag zur Berechnung der Luftschrauben, by Claude Dornier. The second part is a workmanlike development of Drzewiecki's theory of air and water screws. Like all theories which offer a reasonable agreement between theory and experiment, the treatment is based on the analogy between an element of airscrew blade, and a lifting surface.

The author has had the great advantage of testing his theory against actual tests on Zeppelin airscrews.

Nearly half the book, pp. 16-64 out of 108, is somewhat unprofitably spent on the study of airscrews at a fixed point—not the most important part of the subject.

A theory is developed and the agreement shown on page 27, Table 4, and page 28, Table 6, is quite satisfactory as a first approximation.

The second part, pp. 65-108, as already stated, follows more or less closely the method of Drzewiecki.

Unfortunately no direct comparisons between calculated and observed thrusts and turning moments of airscrews moving through the air are given.

No doubt, however, the coefficients occurring in the theory have been corrected by experience obtained in these tests.

Die Gesetze des Wasser und Luftwiderstandes, Dr. O. Martienssen. Chapters I. to VII., 91 pages out of 131, give a highly compressed summary of the mathematical theory of ideal hydrodynamics.

While the value of this theory is not to be denied in preparing the mind to think in terms of lines of flow and pressures, it has so far produced no arithmetical results comparable in accuracy with the experimental values obtained in the wind tunnel.

Chapter VIII. gives a brief summary of experimental results—chiefly Eiffel's.

Chapter IX. deals briefly with gliding flight (7 pages), flapping flight (5 pages), and helicopter flight ($2\frac{1}{2}$ pages).

Chapter X. on stability (13 pages) can only be described as extremely ill-informed.

Chapter XI. on airscrews gives a brief and fairly useful account of Drzewiecki's theory and quotes Eiffel's tests. (G. Eiffel, Complément 1911, pp. 229-260.)

On the whole a poorly balanced book by no means well supplied with references to the really useful experimental and theoretical work available at the date of publication.

Das Naturgesetz des freien Schwebens der Vögel. F. H. C. Mordhorst. It is difficult to find a *raison de publication* for such a pamphlet. The argument is remote from the generally accepted body of aerodynamical results.

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In eleven pages it would be scarcely possible to summarise usefully the elements of bird flight or any other flight, even if these elements were thoroughly grasped.

A. R. L.

How to Understand Aeroplanes. S. L. Walkden. London: Published for the Author by Percival Marshall & Co. 1914. pp. 99 + XVIII. Figs. Price 1s.

The "preface, résumé and introduction" *(sic)* of this book starts: "Aeroplanes are not being designed and flown to-day in the same way that they were in the old fly-and-tumble-even-on-a-calm-day period of 1909-12 . . . in the autumn of 1912, *something happened* . . . the same old aeroplanes emerged from their sheds, but this time to fly—*really to fly*! . . . It is the object of this book to explain as plainly as possible the change that was made in the construction of aeroplanes, and so satisfy the curiosity there is concerning it. . . . The more complete and interesting developments of these subjects are contained in the author's well-known larger text book, 'Aeroplanes in Gusts, Soaring Flight and Stability' (2nd edition), published by Messrs. E. and F. N. Spon, Ltd.; and it was the ampler information of that book which in the autumn of 1912, gave such an impetus to the construction of aeroplanes in the prevailing successful manner."

The quotation of the above words is sufficient to give those familiar with aeronautics a clear insight into the uselessness of this book. It is, however, more than useless; it is pernicious. The easy assurance with which, in this and the larger book, the author juggles with a collection of partial statements of fact so that he is able to "prove" exactly what he wishes, will unfortunately lead the undiscerning to believe that the author really knows all about it, and that the improvement of aeroplanes is largely due to his efforts. It would need a review longer than the book itself fully to expose all the fallacies therein. The best antidote to such unreliable treatises is, however, a fairly extended course of reading of books that have a real claim to be considered helpful. Those who have followed this course will then be able to read Mr. Walkden's books with considerable pleasure, their unconscious humour being a welcome relief from heavier studies.

We cannot allow the illustrations to pass without a word of comment. The author states that it gives him "great pleasure to acknowledge his deep indebtedness to the artist who has contributed various pictorial designs, particularly those on pages 7, 13, 15, 21, 71, and the one facing page 76. In addition to ornamenting the book they will be found an indispensable aid in understanding quickly and vividly, by an appeal to the eye, the meanings of the pages to which they refer." We can only add that it is impossible to say which has given us the greater pleasure, the letterpress or the "various pictorial designs."

The Flying Book, the Aviation World Who's Who and Industrial Directory. The Aviation World Publishing Co. London: Longmans Green & Co. 1914. pp. 184. Illus. Price 2s. 6d.

It is much to be regretted that a firm of publishers that has so greatly assisted Aeronautics by the publication of books of the calibre of, for example, Duchêne's "Mechanics of the Aeroplane" and Hamel and Turner's "Flying," should have been led to publish so feeble a production as "The Flying Book." A thoroughly good and reliable aeronautical pocket-book is much wanted in this country, and the previous attempts that have been made to furnish it have been entirely inadequate. At this time of day, however, with the excellent German "Taschen-

buch der Luftflotten" before him, there is no excuse for the compiler of so amateurish a production as the work now under review. The book consists of two short introductory articles, followed by sections devoted to Aero Clubs and Societies, Modern Aeroplanes, Modern Aero Motors, Who's Who in Aviation, Industrial Directory (British, American, French, and German firms), Military and Naval Aviation, and a few conversion tables at the end. Had these heads been properly covered the book would have been useful; the matter, however, is inadequate and full of inaccuracies.

Under the title of "A Hundred Years of Aeroplane Construction" Mr. A. E. Berriman opens with a very readable little treatise, which, however, does not say much about actual aeroplane construction. Mr. W. E. de B. Whittaker has three and a half pages on "Military Aeronautics," which contain much useful comment, although unduly dogmatic in parts.

The section "Aero Clubs and Societies" appears to have been "lifted," with very slight modifications, from the similar section in the "Aviation Pocket Book for 1913," by R. Borlase Matthews (London: Crosby Lockwood and Co., 1913), and contains much the same errors. The slight editing that it has undergone has evidently been undertaken by one quite out of touch with Aeronautics in this country. For example, Roger Wallace appears on the Committee of the Royal Aero Club, although he resigned many months ago. A reference to the official organ of the Club would have set right the compiler of the list now under review, and would also have given the Council of the Aeronautical Society, which is as equally deserving of inclusion as the R.Ae.C. Committee. Moreover, the same gentlemen are in many instances on both bodies. The Aeronautical Society appears twice—first amongst "Other National Associations," when the address is given correctly, but the Secretary is stated to be Colonel Fullerton (who relinquished the duties in 1909!), and secondly amongst "Local Associations," when the address is given as 52, Victoria Street. (The Society left Victoria Street in the beginning of 1912.) This list of "Local Associations" is, in fact, a most amusing production. It contains the long-defunct Aeroplane Club, and is apparently inflated by the inclusion of other clubs twice under different names. For example, we find the "Heatherfield Aero Club," of Brighton Road, Sutton, Surrey, and the "Surrey Aero Club," of Heatherfield, Brighton Road, Sutton, Surrey. The "Aero Club League" and the "Royal Aero Club League" also are both located at 166, Piccadilly. The East London College Aeronautical Research Society is included, but the similar body at the Northampton Polytechnic is omitted. The gem, however, of the list is the inclusion as a "Local Association" of the National Physical Laboratory!

The section "Modern Aeroplanes," in which side-elevations of many typical machines are given, together with dimensions and description, somewhat redeems the book. The illustrations should, however, have included a plan drawing, and more care should have been taken to indicate the year of each particular type. Without examining this list in detail we note that it is confessed at the outset that "the productions of one or two quite important firms are not described herein." It is rather confusing, too, to read that the Dunne machines "are perhaps the most successful yet produced so far as absolute automatic stability is concerned," and then to read on the very next page that the Etrich machines "constitute what are perhaps the most successful attempts at natural inherent stability aeroplanes" *(sic)*. In the desire to be complimentary our compiler has apparently fallen into the error of thinking that the Dunne and Etrich systems are distinguishable as "automatic" and "inherent" respectively!

In describing the Wright machine it is stated that this does not differ very much from "the historic machine which made about *(sic)* the first power-driven flight as far back as 1905." Had the compiler pursued his aeronautical studies as far back as December, 1903, he might have discovered that the Wright Brothers had a historic machine at that date that was making power-driven flights.

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Facing pages 47 and 75 are diagrams purporting to name the details of a monoplane and biplane respectively. The definitions there given, however, are not consistent among themselves, and do not agree with the Technical Terms settled by the representative Committee of the Aeronautical Society, and recently published in the Press.

"Modern Aero Motors" contains descriptions with small and rather inadequate diagrams of many aero motors.

"Who's Who in Aviation" contains some interesting biographies, but cannot be regarded as at all adequate. It is difficult to understand on what principles certain names have been omitted, whilst space is taken up with such details as "had what might have been a serious accident on Deperdussin monoplane at start of 'Daily Mail' Circuit of Britain Aeroplane Race." The "Camber *(sic)* Lectures on Aeronautics," placed to the credit of Mr. C. C. Turner, have hitherto escaped our notice.

The "Industrial Directory" contains the names of many aeronautical and allied firms. The carelessness noticeable throughout the book, however, leads to the appearance of the "Stern Gonnerborn *(sic)* Oil Company" and other similar slips.

"Military and Naval Aviation" gives particulars of the establishments of Great Britain, Belgium, France, and Germany, but in a quite inadequate manner. A full statement of the Royal Flying Corps "as on July 1914" *(sic)* is given, so that presumably the statement that Great Britain possessed "about 80 aeroplanes in efficient condition" would also be "as on July, 1914." The fact that very soon after the outbreak of war in August over 100 machines were in service on the Continent alone seems to indicate that 80 was an under, rather than an over statement of the total machines available.

The production of an adequate aeronautical pocket book is very much to be desired. It is to be hoped that Messrs. Longmans Green and Co. wish to produce it, and that they will entrust the task to competent hands. In any event, however, it is improbable that it can be done to sell at so low a figure as half-a-crown.

RESULT OF THE NAVAL AND MILITARY AEROPLANE ENGINE COMPETITION, 1914.

The Army Council have decided, on the recommendation of the Judges Committee, to make the following awards:—

The prize of £5,000 to the Green Engine Company for the Green 100 h.p. water-cooled engine No. 1, which best fulfilled the requirements of the competition and possessed the greatest percentage of attributes desirable in an aeroplane engine.

Awards of £100 for each engine to the undermentioned firms in respect of the engines entered by them which performed successfully the eliminating trial of a six hours' continuous run at full power.

Argylls, Ltd.	£100
Beardmore Austro-Daimler Engine Co.	£200
British Anzani Engine Co.	£100
Dudbridge Ironworks Co.	£300
Gnome Engine Co.	£200
Green Engine Co.	£100
Sunbeam Motor Car Co.	£100
Wolseley Tool and Motor Car Co.	£200

War Office, 15th October, 1914.

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